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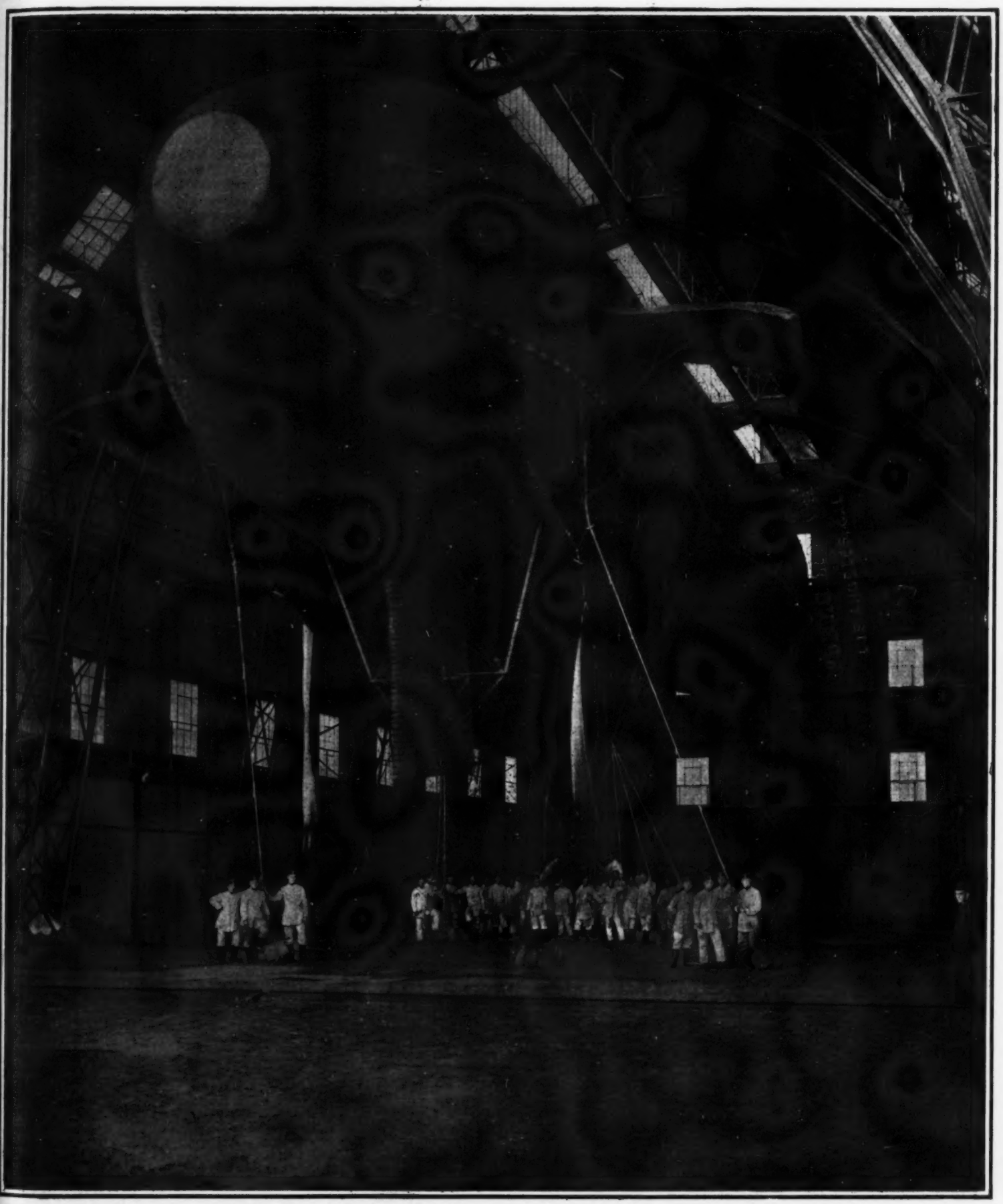


End view of Parseval airship in its shed, showing the stabilizing fins at the sides of the envelope and the vertical rudder beneath.

THE MILITARY PARSEVAL AIRSHIP USED BY THE GERMAN ARMY.—[See page 228.]

The Germplasm as a Stereochemic System—I*

Every Individual is a Chemical Entity That Differs in Characteristic Particulars from Every Other

By Edward Tyson Reichert, University of Pennsylvania

THE discovery, in 1883, by Dr. S. Weir Mitchell and myself that the toxic principles of the venoms of serpents are albuminous marked an era in the chemistry, physiology and pathology of proteins, and among other things laid the foundation of our knowledge of bacterial and other toxalbumins. Since that time our information of the properties of albuminous substances, then extremely meager and somewhat chaotic, has greatly advanced, and many investigations have been made to determine the precise nature of these poisons, with the effect of more or less modifying the statements we then set forth. The astonishing fact that these terribly lethal substances were found by the tests of the day to be proteins, and that apart from their toxic properties they were indistinguishable from corresponding bodies that are ingested as food or derived therefrom by the processes of digestion, or found as normal constituents of the living tissues generally, naturally led me to much speculation and ultimately to the pursuit of the very elaborate series of researches that I have been carrying on during the past decade under the auspices of the Carnegie Institution of Washington, reports of two of which have appeared as Publications Nos. 116 and 173.

It would be futile for me to attempt, within the necessarily restricted time that can reasonably be allotted to the reading of a communication, to present in a satisfactory form even the briefest summary of the very voluminous results and conclusions that are embodied in these works, or even an outline of their bearings, upon a vast number of problems of normal and abnormal biology, so that perforce my remarks shall be limited to a fragment—a fragment which bears upon one of the most baffling yet all-absorbing problems of life, why "like begets like."

A. THE SPECIFICITY OF STEREOISOMERIDES IN RELATION TO GENERA, SPECIES, ETC.

These researches have as their essential basis the conception that *in different organisms corresponding complex organic substances that constitute the supreme structural components of protoplasm and the major synthetic products of protoplasmic activity are not in any case absolutely identical in chemical constitution, and that each such substance may exist in countless modifications, each modification being characteristic of the form of protoplasm, the organ, the individual, the sex, the species and the genus.* This conception was supported not only by the extraordinary differences noted between the albuminous substances of venom and those of other parts of the serpent, but also by the results of the investigations of Hanriot who described marked differences in the properties of the lipases of the pancreatic juice and the blood; of Hoppe-Seyler and others who stated that the pepsins of cold- and warm-blooded animals are not identical; of Wróblewsky and others who recorded differences in the pepsins of mammals; of Kossell and his students who found that the protamins obtained from the spermatozoa of different species of fish are not identical; and of various observers who have noted that the erythrocytes of one species when injected into the blood of another are in the nature of foreign bodies and rapidly destroyed. During subsequent years, and especially very recently, data have been rapidly accumulating along many and diverse lines of investigation which collectively indicate that every individual is a chemical entity that differs in characteristic particulars from every other. To anyone familiar with the advances of biochemistry and with the trend of scientific progress toward the explanation of vital phenomena on a physico-chemical basis, it will be obvious that if the conception of the non-uniform constitution of corresponding proteins and other corresponding complex organic substances in different organisms and parts of organisms were found to be justified by the results of laboratory investigation a bewildering field of speculation, reasoning and investigation would be laid open—a field so extensive as to include every domain of biological science, and seemingly to render possible, and even probable, a logical explanation of the mechanisms underlying the differentiation of individuals, sex, varieties, species and genera; of the causes of fluctuations and mutations; of the phenomena of Mendelism and heredity in general; of the processes of fecundation and sex-determination; of the tolerance of certain organisms to organic poisons that may be extremely virulent to other forms of life; of tumor formation, reversions, malformations and monsters; of anaphylaxis, certain toxemias, immunities, etc.; and of a vast number of other phenomena of normal and abnormal life which as yet are partially or wholly clothed in mystery.

Some years previous to the discovery of the nature of the lethal constituents of venoms, Pasteur found that there exist three kinds of tartaric acid which, because of different effects on the ray of polarized light, are distinguished as the dextro-, lævo- and racemic-tartaric acids, the dextro form rotating the ray to the right, the lævo form to the left, and the racemic form not at all. When these acids were subjected in separate solutions to the actions of *Penicillium glaucum* fermentation proceeded in the dextro form, but not in the lævo form, while in the solution of the racemic acid, which is a mixture of the dextro and lævo acids, the dextro form disappeared, leaving the lævo moiety unaffected. All three acids have the same chemical composition and chemical properties but differ strikingly in their effects on polarized light and in nutritive properties. Identical or corresponding peculiarities have since been recorded in relation to a large number of substances. Thus, of the twelve known forms of hexoses, or glucoses, only the dextro forms are fermentable, that is, capable of being used by certain low organisms as food, but not all are thus available, and, moreover, those which are show marked differences in the degree of fermentability. In the case of other substances *Penicillium* may consume the lævo form but not the dextro form. Other organisms show similar selectivities, using either dextro or lævo form, or both, but in the latter case in unequal degree. Even more striking instances have been recorded in the actions of poisons, as for instance, dextro-nicotine is only half as toxic as the lævo form; dextro-adrenalin has only one twelfth the power of the lævo form; racemic-cocaine has a quicker and more intense but less lasting action than the lævo form; the asparagines, hyoscines, hyoscyamines and other substances have been found to exhibit marked differences in accordance with variations in their optical properties. With other bodies belonging to this category it may be found that one form is sweet while another is tasteless; another may be odorous but its enantiomorphous form without odor.

To the foregoing there may be added examples of other substances that exist in several forms but which physico-chemically belong to a different class. Thus, nitroglycerine may exist in forms that are so different that under given conditions of temperature and percussion one is explosive and the other non-explosive. Differences in substances which are found in allotropic forms may be as marked as in any of the preceding illustrations, as for instance, in the case of phosphorus, which is familiar as the yellow, white, black and red varieties, all of which with the exception of red phosphorus are exceedingly poisonous while the latter is inert. The ortho, meta and para forms of a given substance may exhibit more or less marked physiological and toxicological variations, and so on.

The explanation of the remarkable differences shown by these substances, which differences are paralleled by those manifested by the lethal and inocuous proteins of the serpent, the pepsins, the protamins and the red blood corpuscles, is to be found in the results of two independent but intimately related lines of physico-chemical research: (1) The investigations of Van't Hoff and LeBel and subsequent observers which have laid the foundation of a new, and to the biologist and physician, an extraordinarily important development of chemistry known as stereochemistry—a department that treats of the arrangements of the atoms, groups and masses of molecules, or in other words of intramolecular arrangement or configuration of molecular components in the three dimensions of space. (2) The investigations of Willard Gibbs and others which have given us the "phase rule" which defines the phases or forms in which a given substance or combination of substances may exist owing to differences in intramolecular and extramolecular arrangements and concentration of their components in relation to temperature and pressure.

According to stereochemistry a given substance may exist in multiple forms dependent upon differences in the configuration of the molecule, all of which forms have in common the fundamental chemical characteristics of a given prototype, yet each may have certain properties which positively distinguish it from the others. Theoretically, such substances as serum albumin, serum globulin, hemoglobin, starch, glycogen and chlorophyl may be produced by nature in countless modified forms owing to differences in intramolecular arrangements. Miescher has estimated that the serum globulin molecule may exist in a thousand million forms. Substances that exist in such multiple forms of a prototype are distinguished as stereoisomers. The remarkable fact has been noted by Fischer and others that stereoisomers may exhibit as great or even greater differences in their properties than those manifested by even closely related isomers, which latter in comparison with stereoisomers are distantly if at all chemically related. As already instanced, so slight a change in molecular configuration as gives rise to dextro and lævo forms may be sufficient to cause definite and characteristic and even profound differences in physical, nutritive and physiological properties.

In accordance with the "phase rule" a substance or a combination of substances may exist in the form of heterogeneous or homogeneous systems, a heterogeneous system consisting of a number of homogeneous systems, each of which latter is a manifestation of an individual phase and distinguishable from the others by physical, mechanical, chemical or physiological properties. The number of phases of a heterogeneous system increases with the number of component systems, and the number of the latter is in direct relationship to the number of independent variable constituents. Therefore, by means of variations of either or both intramolecular or extramolecular arrangement the number of forms of a substance or combination of substances may range from few to infinite.

Our means of differentiating stereoisomers are, on the whole, limited and for the most part crude, and while it has been found that differences so marked as those referred to may be detected by the ordinary procedures it seems obvious that the inherent limitations of such methods render them inadequate where a large number of stereoisomerides or related bodies which may exhibit only obscure modifications are to be definitely differentiated, so that other and more sensitive methods must be sought, or at least special methods that are adapted to exceptional conditions. The results of much preliminary investigation in this direction led in one research to the adoption of the crystallographic method, especially the use of the polarizing microscope, which in its very modern developments of analysis has demonstrated that substances which have different molecular structures exhibit corresponding differences in crystalline form and polariscopic properties; and, moreover, that the "optical reactions" may be found to be as distinctive and as exact analytically as the reactions obtained by the conventional methods of the chemist. Furthermore, the necessities of the hypothesis demanded the selection of a substance for study of a character which upon theoretical grounds might be expected to exist in nature widely distributed and readily procurable, and, as a consequence, hemoglobin was selected.

In the investigation of the hemoglobins I had as a coworker Prof. Amos Peaslee Brown. Hemoglobins were examined that were obtained from over 100 animals, representing a large variety of species, genera and families. From the data recorded certain facts are especially conspicuous, among which may be mentioned the following:

1. The constant recurrence of certain angles, plane and dihedral, in the hemoglobins of various species, even when the species are widely separated and the crystals belong to various crystal systems. This feature indicates a common structure of the hemoglobin molecules whatever their source.

2. The constant recurrence of certain types of twinning in the hemoglobins, and the prevalence of mimosie. This has the same significance as the foregoing.

3. The constancy of generic characters in the crystals. The crystals of the various species of any genus belong to a crystallographic group. When their characters are tabulated they at once recall crystallographic groups of inorganic compounds. The crystals of the genus *Felis* constitute an isomorphous group which is as strictly isomorphous as the groups of rhombohedral and orthorhombic carbonates among minerals, or the more complex molecules of the members of the group of monosymmetric double sulphates.

4. The crystallographic specificity in relation to species. The crystals of each species of a genus, when they are favorably developed for examination in the polarizing microscope, can usually be distinguished from each other by definite angles and other properties, while preserving the isomorphous character belonging to the genus. Where on account of difficulty of measurement the differences cannot be given a quantitative value variations in habit and mode of growth of the crystals often show specific differences.

5. The occurrence of several types of oxyhemoglobin in members of certain genera. In some species the oxyhemoglobin is dimorphous and in other trimorphous.

*Read by title at the meeting of the American Philosophical Society, April 25th, 1914, and in full before the Society of Normal and Pathological Physiology of the University of Pennsylvania, April 28th, 1914.

Where several types of crystals occur in this way in the species of a genus the crystals of each type may be arranged in an isomorphous series. In other words, certain genera as regards the hemoglobins are isodimorphous and others isotrimorphous.

6. When orders, families, genera or species are well-separated the hemoglobins are correspondingly markedly differentiated. For instance, so different are the hemoglobins of *Aves*, *Marsupialia*, *Ungulata* and *Rodentia* that there would be no more likelihood of confounding the hemoglobins than there would be of mistaking the animals themselves. Even where there is much less zoological separation, as in the case of the genera of a given family, but where there is well-marked zoological distinction, the hemoglobins are so different as to permit readily of positive diagnosis. When, however, the relationships are close the hemoglobins are correspondingly close, so that in instances of an alliance such as in *Canis*, *Vulpes* and *Urocyon*, which genera years ago were included in one genus (and doubtless correctly) the hemoglobins are very much alike, and in these cases they may exhibit closer resemblances than may be found in general in specimens obtained from well-separated species of a genus.

So distinctive zoologically are these modified forms of hemoglobins that we had no difficulty in recognizing that the common white rat is the albino of *Mus norvegicus* (*Mus norvegicus albus* Hatai) and not of *Mus rattus* as almost universally stated, and that Ursidæ are related to Phocidæ (as suggested by Mivart 30 years ago) but not to Canidæ as stated in modern works on zoology. Moreover, we were quick to detect errors in labeling, as for instance, when a specimen marked as coming from a species of *Papio* was found to belong to one of the Felidæ. Generic forms of hemoglobin when obtained from well-separated genera are, in fact, so different in their molecular structures that when any two are together in solution they do not fuse to form a single kind of hemoglobin or a homogeneous solution, but continue as discrete disunited particles, so that when crystallization occurs each crystallizes independently of the other and without modification other than that which is dependent upon such incidental conditions as are to be taken into account ordinarily during crystallization. Thus, the hemoglobin of the dog crystallizes in rhombic prisms which have a diamond-shaped cross-section; that of the guinea-pig in tetrahedra; that of the squirrel in hexagonal plates; and that of the rat in elongated six-sided plates. When any two of these hemoglobins are together in solution and crystallization occurs, each appears in its own form. Such phenomena indicate that the structures of the hemoglobin molecules are quite different; in fact, more differentiated than the molecules of members of an isomorphous group of simple carbonates, such as the carbonates of calcium and magnesium which when in separate solutions crystallize in rhombohedrons whose corresponding angles differ 2 deg. 15 min., but which when in molecular union, as in the mineral dolomite, crystallize as a single substance which has an intermediate angle.

Upon the basis of our data it is not going too far to assume that it has been satisfactorily demonstrated theoretically, inferentially and experimentally that at least this one substance (hemoglobin) may exist in an inconceivable number of stereisomeric forms,[2] each form being peculiar to at least genus and species and so decidedly differentiated as to render the "hemoglobin crystal test" more sensitive in the recognition of animals and animal relationships than the "zooprecipitin test."

Subsequent to the research referred to, investigations have been pursued in the study of hemoglobins from various additional sources, especially from representatives of *Primates*, with the result in the latter case of finding indubitable evidence of an ancestral alliance of man and the man-like apes.

More or less elaborate studies by crystallographic and other methods have also been made with other albuminous substances and with starches, glycogens, phytocholesterins, chlorophyls and other complex synthetic products of animal and plant life, especially with starches, of which over 300 specimens were examined that were obtained from different plant sources, including representatives of a considerable number of families, genera, species, varieties and hybrids. In all of these investigations the results are not only in full accord with those of the hemoglobin researches but also in some instances of broader significance because by better methods of differentiation in some cases it was found possible to recognize not only peculiarities as regards genus or species but also varieties and hybrids, and even to trace in hybrids with marked definiteness the transmission of parental characteristics.

Summing up the results of these independent but interwoven researches we find that the modified forms of each of these substances lend themselves to a very definite system of classification, and to one that is in general accord with that of the botanist and zoologist, that is, each genus is characterized by a distinctive type of hemoglobin, albumin, starch, etc., as the case may be, which may be designated the generic-type; every species of the genus will have a modification of this type, which is a species-type, or generic primary sub-type; and every variety of a species will have a modification of the species-type, that is a variety-type, or generic secondary sub-type, or species sub-type. In fact, it seems clear that with revisions of present classifications that are certain to come there will be found definite family types; and, moreover, that with improved methods of differentiation there will be discovered positively distinctive sex- and individual-types. This last statement already has support in the results of collateral lines of research which bear upon the specificities of enzymes, anaphylaxis, precipitin reactions, immune sera, etc.

From the foregoing data it seems obvious that *the complex organic substances which may be assumed to constitute the essential fundamental constituents of protoplasm and the immediate complex synthetic products of protoplasmic activity may exist in exceedingly numerous or even countless stereoisomeric forms, each form being peculiarly and specifically modified in relation to genus, species, variety, race, sex, individual or even part of an individual.*

B. PROTOPLASM A COMPLEX STEREOISOMERIC SYSTEM.

The next logical step in our investigation is manifestly the study of the bearings of these stereoisomers, as such and in their variable combinations and associations, upon the structure, processes and products of protoplasm. Protoplasm according to the modern developments of biochemistry is to be regarded as being in the nature of an extremely complex, labile aggregate of proteins, fats, carbohydrates and other substances that are peculiarly associated to constitute a physico-chemical mechanism. The possible number of "phases" in which such a system can exist varies with the forms of the stereoisomerides and in general with the number and independent variability of the components. In such a mechanism we conceive that the number of variables is inconceivably great. From analogy we believe that such mechanisms are so extremely sensitive that the properties and processes may be modified by even so slight a change as the substitution of one form of stereoisomeride for another of the same prototype. Were it practicable to examine all of the most complex of the organic structural components of protoplasm it doubtless would be found that every one exists in a form that is peculiar to the individual and his position in classification. Moreover, we must conceive that the components of protoplasm are as specific in relation to the form of protoplasm as are the peculiar forms of stereoisomers, so that different forms of protoplasm are characterized physico-chemically (1) by the peculiarities of the stereoisomerides, and (2) by the peculiarities of the kinds, combinations, associations and arrangements of the components in the three dimensions of space.

In accordance with the foregoing, the human organism may be regarded as being a highly organized composite of heterogeneous physico-chemical systems that are composed of a vast number of parts, each such part representing a particular "phase" of the system and being physically, mechanically, chemically and functionally an individual interacting unit of the aggregate. Hence, it follows that the sum or totality of these peculiarly modified stereoisomers *per se*, and of their arrangements with the associated components constitutes a "stereochemic system" that is peculiar to the cell; that the sum of the cell-systems is peculiar to the tissue; that the sum of the tissue-systems is peculiar to the organ; and that the sum of the organ-systems is peculiar to the individual.

While the living organism had been for years recognized as being in the nature of an exceedingly complex physico-chemical aggregate of interacting independent and interdependent parts that constitute a single working unit, it has been in only recent years that the mechanisms that bring about co-operative activities of the various parts has been made clear. The governing influences of the nervous system were found inadequate even in the highest organisms, not to speak of forms of life in which such actions occur but in which there is apparently a total absence of nervous matter. As an associate of the nervous system, and doubtless far antedating it in organic evolution, is a correlative mechanism of a chemical character that is of the greatest importance, and doubtless equally so throughout the whole range of living organisms from the lowest to the highest. Every living cell whether it be in the form of a unicellular organism or a component of a multicellular organism is undoubtedly in the nature of a heterogeneous stereochemic system, each of the component parts of the system forming substances which may affect directly or indirectly the activities of the processes of the other parts; likewise every cell of a multicellular organism is not only in itself a heterogeneous system but a part of a number of associated heterogeneous systems and which by virtue of certain of its products, with or without the agency of the blood-vascular or lymph-vascular systems, may exercise influences upon other structures, which structures may have or seemingly not have either structural or physiological relationship. Thus we find that a secretion formed in the pyloric glands of the gastric mucosa may excite the glands of the cardia; that growth is determined by some product or products of the pituitary body that are carried to the various structures; that the liver, pancreas and intestinal glands are excited to secretory activity by a peculiar substance formed in the duodenal and jejunal mucosæ; that carbohydrate metabolism in the liver and muscle is influenced to a profound degree by hormones that are formed in the pancreas; that lactation is determined essentially by substances derived from the corpus luteum, placenta and involuting womb; that the periods of ovulation and menstruation are inhibited by secretions of the corpus luteum; that vitally important states of activity of the generative organs are directly associated with functions of the adrenal glands; and that normal development, especially of secondary sexual characters, is intimately related to the ovaries and testicles. To these extraordinary correlations might be added many others. Some of the bodily structures are in this way so definitely associated in their activities as to constitute co-operating or interacting systems, so that the tissue products are complementary, supplementary, synergistic or antagonistic in their influences upon given structures. Such correlations must be, for perfectly obvious reasons, one of the most primitive forms of interprotoplasmic correlation, and we are justified, upon the basis of our present knowledge, in the conclusion that each active part of a cell, each cell, each tissue and each organ contributes products which may affect the activities of functionally related or unrelated parts. Hence would follow the dictum that *not only is every part of a cell, every cell, every tissue and every organ an individualized stereochemic unit but also that its operations, and hence the nature of its products, must be subject directly or indirectly to the influence of every other active part of the organism, however different the structures and functions may be.*

(*To be concluded.*)

[2] Even if we assume that the different forms are not, strictly speaking, stereoisomers it must be admitted that hemoglobin exists in forms that are specifically modified in relation to genera and species.

Elevators for Eels

A NEW method of eel-culture practised by a Dane named Nielsen is described in the annual government report on the fresh water fisheries of England and Wales. Nielsen is the proprietor of a piece of low-lying land on the Ise Fjord in the island of Zeeland, so banked in as to form a pond of about 432 acres, which is on an average about 2 feet deep. The water in the pond is somewhat brackish, and this permits of the development of abundant quantities of Mysidæ, and upon these the eels feed and thrive. The proprietor has contrived, however, that either salt water from the Fjord or fresh water from the adjacent canal can be pumped into the lake as desired. The eel spends the greater part of its life in fresh water; but on attaining sexual maturity it instinctively seeks the sea, where it spawns (this statement appears to apply to all the eels of Western Europe) far out in the Atlantic in the neighborhood of the Sargasso Sea. The young eels, in their helpless larval stage, drift with the ocean currents until they become elvers, when they make their way into fresh waters, where they remain till they have reached the stage of maturity, at which nature urges them to return to the sea which gave them birth.

Nielsen observed that the elvers annually appeared in the Ise Fjord alongside his lagoon in the early spring months, and he conceived the ingenious idea of attracting them into a trap by means of a supply of fresh water, which is allowed to run through a sluice constructed in the bank of the lagoon, and thence down a sloping platform into the Fjord. He found that when he wished to discharge a volume of water through the sluice sufficient to have such an effect upon the surrounding salt water as to attract the elvers to its neighborhood, the flow was too strong to allow the elvers to ascend the slope without assistance. He therefore constructed bands of twisted straw, which are attached to the sloping platform, and allowed to drift out into the Fjord. The elvers are able to wriggle along these bands, and by means of them to make their way up the slope into a specially constructed trap, from which they are easily taken, and being counted, are transferred to the lagoon. By means of the trap, some 50,000 elvers were introduced in 1905, and in subsequent years the number has varied from about 60,000 in 1906 to about 300,000 in 1913.

When, on the other hand, Nielson requires ripe, full-grown eels for the market, he again takes advantage of the natural instinct of the mature eel to migrate toward salt water. Salt water from the Fjord is pumped over the dam into the pond through boxes specially constructed for catching the eels, which, being attracted by the salt water, enter the boxes, and are there trapped. By this means as many as 300 pounds of eels have been caught in a single night, and the proprietor can take eels when he pleases. In 1913 it was estimated that the weight of eels taken was about 13,000 pounds.—*The English Mechanic.*

The Parseval Airship Used by the German Army

A Type of Non-Rigid Dirigible That has Proved a Success Abroad

By Carl Dienstbach

WHEN the "air balloon" was invented by the Montgolfiers and Charles, the belief was general that the most difficult part of the problem of human flight was then solved, and that it would require but slight additions to the inflated bag to make it a useful means of transportation. Hundreds of schemes and attempts were suggested to supply the "slight additions." How astonished one of these early naïf "improvers" would be if he could see his dream come true!

Perhaps the most practical airship of our day is the Parseval, which in truth may be called a gas bag with slight additions. The Parseval airship owes its great advantages precisely to the fact that the inventor did not aim at creating something essentially different from a balloon, that he intended to preserve every single good and practical feature of the time-honored "spherical," and that he strove for his comparatively modest goal with so much ingenuity.

A sight not altogether unfamiliar, would greet the eye of Parseval's eighteenth century admirer. First, he would be pleased to learn that the aircraft of his own day, after remaining exactly the same for over a century, had suddenly seen great technical improvement at the beginning of the twentieth century. The gas-retaining qualities, the strength and toughness, the lightness of the new double rubberized and biased balloon cloth would be a revelation to him. Without that fabric the new airship would never have come into existence. But what should otherwise appear really novel to him might only seem as if it were like a "touch" added here and there, but the "touch" of a master hand—comparable to the slight application of the brush, by which great painters are known to have turned a pupil's work into an everlasting masterpiece. Thus the fundamental change from the spherical balloon—the elongated gas bag—means in the Parseval an almost true "form of minimum resistance." This fact is due to the very propitious circumstances which favored the work of Major von Parseval.

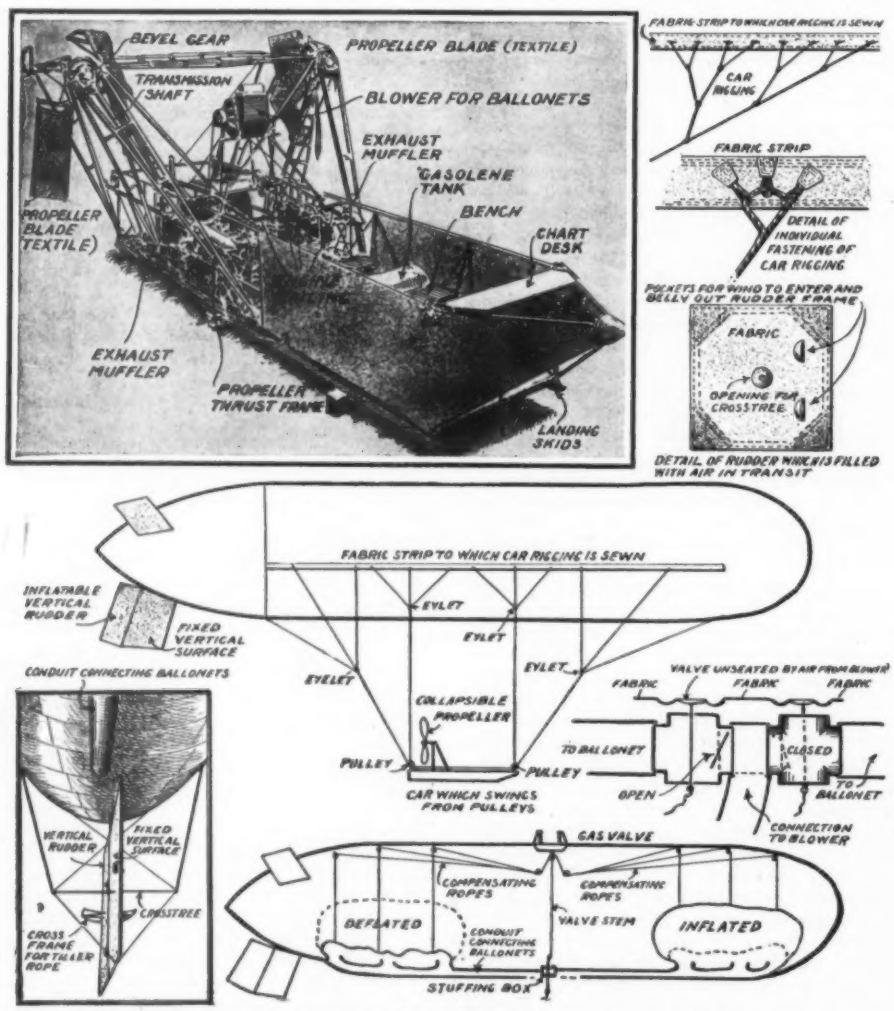
It happened that the great German "Society for the Study of Motor Aeronautics" was founded at the initiative of the emperor at the exact date that his first experimental airship was tested. This organization counted among its members the most prominent financiers and the ablest scientists and engineers of the fatherland. Major von Parseval's work presently became the point around which its endeavors crystallized.

All its energies were soon concentrated on the improvement of his simple system, which was justly recognized to promise immediate success. After the model of Prof. Zahm's aero-dynamical laboratory in Washington, the society built a laboratory for aero-dynamical research at Goettingen, and put Prof. Prandl of the Goettingen University in charge. In a big Zahm wind tunnel the best shape for the hull was developed on tin models, thus verifying the prediction of Prof. Woodward, president of the St. Louis International Aeronautical Conference, 1904, that the result of Prof. Zahm's and Prof. Nipher's work combined (the latter on the distribution of wind pressure on structures), both submitted to that conference, would result in a form of least resistance for the hull of an airship. Prof. Prandl investigated the pressure by means of small holes bored along the whole surface of his models and communicating with many interior compartments, which were alternately connected to pressure gages. He was thus enabled to draw accurate curves. The almost spherical front of the shape evolved by Prof. Prandl would seem most familiar to the man of the eighteenth century. The big fish-like steadying fins at its stern, so conspicuous by their simplicity, would be a surprise. These are, indeed, the principal contributions of the twentieth century to the old balloon. Invented by the late Col. Renard as early as 1884, they remained a secret up to 1902. The reason for the specially efficient use to which they were put by Major von Parseval is the fact that he, in a way, had independently reinvented them. Even the rudder is so deftly hinged to these fins that it hardly shows. Yet it has an unusually efficient shape and position.

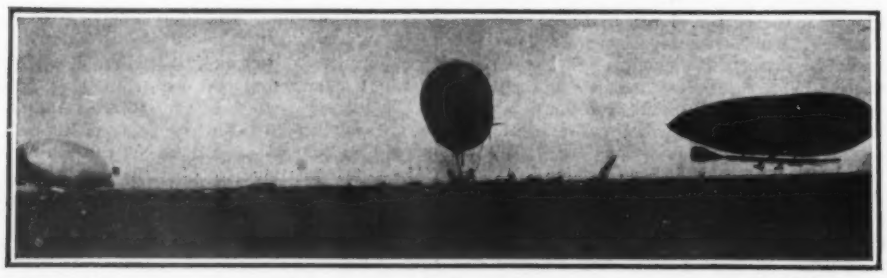
The resemblance of the Parseval to an ordinary spherical is due to the fact that it was evolved from a balloon. Parseval first developed an elongated captive balloon that could be operated in heavy winds. In co-operation with the late Capt. von Siegsfeld, he did this so well that his so-called "Drachen Ballon" is to-day introduced into the military service of most powers. To his airship it is almost as closely related as a glider is to an aeroplane, or a towing barge to a steamer. It offered two formidable problems, steadying it in the wind, and properly suspending the car. To arrive at the nucleus of the Parseval airship nothing more was needed than to modify the "Drachen Ballon." The rounded, sausage-shaped steadying bag of the "Drachen Ballon," whose excessive drag prohibited its use as an airship, was first turned into three rectangular hollow "mattresses" stiffened by internal pressure and part of the balloon. The "Drachen Ballon's" ingenious suspension, flexible to prevent excessive rocking in the gusts, was easily turned into the famous Parseval airship suspension, which allows a "car on wheels" to roll ahead or back on steel ropes, with the air pressure against the gas bag.

To these ingenious devices the Parseval airship owes its existence. Without them it would not be feasible to suspend the car low enough to distribute its weight sufficiently over the whole length of the bag to make it possible to dispense with any sort of a stiffening frame. The ship would pitch so violently that it could not be propelled. Still this very feature is a weak point of the "non-rigid" system. Its inventor personally remarked to the writer, when complimented on the truly beautiful appearance of the "rigging": "Its air resistance is something to be reckoned with." The great saving of weight it permits is thus partly offset. A Parseval has also most of the faults as well as the virtues of an ordinary balloon, while the purely rigid construction, as represented by Zeppelin, Schuette, and others, aims at turning the aerostat into a true "ship." Their goal is infinitely higher, and therefore fundamentally entitled to a more lenient criticism. The ample carrying power of a non-rigid airship makes indeed a large Parseval (type B) a thing of amazing solidity. For instance, the thinnest rope in the suspension has the thickness of a man's finger. The steel wire cables on which the car rolls have the same thickness. The car, detached, as to size and strength, looks almost exactly like a "freak" gasoline launch.

Its board floor, solid as a boat's deck, is 30 feet long and over 6 feet wide. The frame carrying the propellers is made of steel tubes as thick as a man's arm. The center of each propeller is about 12 feet above the floor of the car, and each is also slightly over 10 feet in diameter. The width of each of the four rectangular blades is slightly less than 2 feet. The non-rigid propellers, very inconspicuous when at rest, and directly attached to the car, also increase the resemblance of the Parseval to an ordinary balloon. Each propeller has a girder work hub of steel, skillfully designed to withstand all working stresses with a minimum of material, to which hub four cloth blades are fastened like so



Diagrams showing the constructional details of the Parseval airship.



The Zeppelin. The Parseval. The Gross.

Three typical German airships.

many flags. The blades are made of two strong wire ropes with cross pieces of steel, sewn into a double layer of heavy balloon fabric. Major von Parseval explained to the writer that by correctly proportioning the weight of different parts of the flexible blade to a given speed of revolution and a given pitch, any desired form of the blade could be obtained from centrifugal force acting against the pressure of propulsion. It has indeed been claimed that these blades are more efficient than solid ones. In the newest Parseval ships they are made semi-rigid—just stiff enough to preserve their shape when at rest—as a matter of convenience.

The Parseval power plant has been brought to such a state of reliability that it should furnish a fitting model for any kind of aircraft, especially flying machines. There are, of course, two motors. To insure the highest possible economy when only one motor is running there is a coupling arrangement by which two propellers in tandem may be driven by either motor alone. The girder construction of the hubs has been fashioned into a mechanism that permits altering and even reversing the pitch of the propellers while they are running. This is done by a convenient hand wheel at the side of the car. The pitch is always adjusted to the most economical number of the motor's revolutions. With one motor driving both propellers the pitch is lowered until the propellers run quite as fast as with two motors.

The last reason for the striking resemblance of the Parseval airship to an ordinary balloon is the absence of any horizontal rudders. Steering up and down, i. e., tilting the keel, is effected by a principle similar to that which makes an ordinary balloon go down. Gas is removed from the end to be lowered. It is not lost, but merely transferred to the opposite end, whose lift is thus increased at the same rate that the buoyancy of the other end is diminished. This is done by means of two air ballonets (each with one eighth of the cubic capacity of the gas space) in the opposite ends of the envelope, a powerful blower, driven by a double belt from each motor, and large distributing valves for the air blast. All this forms a specially substantial and conspicuous part of the machinery, and has been designed to stand rough usage. The blower is carried in the propeller frame, some 8 feet above the floor of the car. The vertical air hose leading to the bag is stiffened by strong wooden rings. The large distributing valves of aluminium are at the same time automatic safety valves. They are so attached to the envelope that any excessive gas pressure moves a plunger and allows the air to escape. The gas pressure is relieved in this manner as long as either ballonet contains any air. If both are completely emptied they automatically pull the maneuvering gas valve on top of the envelope open, an arrangement copied from the "Drachen Ballon." There is considerable mechanism inside the gas bag which has never been described. This was sketched for the writer by Major von Parseval himself. In order to keep a certain amount of control over the "convulsions" of the ballonets inside while they swell or collapse, a series of cords is fastened to their upper surface. They are united into one rope that runs over a pulley suspended above either ballonet from the inner "ceiling" of the gas bag. Thus the ballonets are made to swell and collapse more evenly. If excessive expansion of the gas by heat or height should ever squeeze all air out of the ballonets this rope, under tension, would exert a pull strong enough to open the gas valve on top. A single gas valve is thus made to serve as both a maneuvering and a safety valve. The valve stem is led through a stuffing box in the bottom of the bag. Two ripping panels and cords, one at either end, are provided, as in a spherical balloon. For the guidance of the pilot there are four pressure gages, one for each air ballonet and one for each end of the gas space. They register in centimeters of water, and consist of U tubes of glass filled with red liquid. The front end of the car is covered by a chart desk. A compass, designed by Prof. Marcuse, is suspended over the pilot's head, who reads the inverted dial from below. A small vertical steering wheel shaped like that of a ship is directly in front of the chart desk. The pressure gages mentioned are attached to the right "gunwale" of the car, and the lines controlling the distributing valves pass down from above also on starboard. The compass may easily be taken down and with an iron tripod attached to "ship shape" brass fittings sunk into the car's board floor. This is done for nautical measurements of the sun's position. There is, of course, in addition to the usual barograph, barometer, statoscope of the spherical balloon, also an air bubble to indicate the "tilt." The frame of the car is made of steel tubes and T girders, covered with wire netting and heavy canvas. A large cylindrical gasoline tank in a cloth casing serves as a back to an elegant bench upholstered in red leather, running across the car, and dividing it into a "bridge" and "engine room." This bench accommodates six passengers. For the pilot and his aides there are camp chairs. The spacious engine room, with the smart iron railing around the motors, differs in no sense from that of a boat, even as to its minute cleanliness. The motors are of the six-cylinder type, each good for 120 horsepower maximum. They were selected after a competition and have never given trouble. The radiators, arranged like an inverted V, close the car in the rear. They are of aluminium, very imposing, each about five feet square, but quite light. Cooling is effected by powerful blowers set in a casting. These spread the blast evenly over the whole radiating surface. The motors are cranked with the throttle almost closed and the propellers are thrown in by clutches.

The rigging is as elaborate and picturesque as that of a clipper ship. It was found that anything could be attached directly to the gas bag, to reinforcing "patches," which doubled and trebled the thickness of the cloth. There is an "equatorial belt" carrying the suspension, and there are many other "patches," some of them shaped like a star, to hold a single rod. The stabilizing fins are now made of steel frames covered with cloth on both sides. The "air mattress" idea has been dropped, but the cloth is still kept from fluttering by allowing the wind to catch in a "mouth" and blow between the two layers. The tiller rope ends in a steel band that fits around a large semi-circular pulley fastened to the rudder. This insures precise action. The stabilizing planes are held in place by a very simple and strong arrangement of rods and stays fastened to the envelope as described above. The suspension branches back with innumerable "crows' feet" (the original ones made of three loops of rope each, sewn to the equatorial belt) from many short hemp ropes into fewer and fewer wire ropes. Everything is flexible. All loops are lined with fittings of aluminium or steel, allowing the ropes to slide with little friction and preventing excessive wear and tear. The car, with four grooved wheels, rolls on two strong inclined cables of twisted steel wires, into which most of the branch ropes finally consolidate. At the same time it swings like a pendulum with parallel motion from six vertical ropes.

A Parseval's handling is nearly as simple as that of the ordinary round balloon. It has been inflated in the open, and it can be landed, by valve and ripping cords, with safety, with disabled motors in a storm. There are many "handling ropes," each with a series of loops, giving a firmer grip. They hang down from the whole length of the bag, and are an integral part of the rigging.

At Frankfort in 1909, during the International Aeronautic Exposition, where the ship ascended, one of these dragging ropes coiled around a man's legs and raised him into the air like a feather, although the balloon had no surplus lift. Thus the lifting power of the propellers and the tilted hull was forcibly shown. The ship was always actually heavier than the air when it left the ground in a slanting direction. Coming down was harder than going up. The consumption of fuel lightens the ship, and it is considered "unsportsmanlike" to let out gas. The low center of gravity, in spite of the flexible suspension, prevents a tilt as sharp as that of the "Zeppelin III," which swoops down like a hawk. The "Parseval III" must "screw itself down" in many spirals. On one occasion, in bright sunshine, it could not come down at all, much to everybody's amusement.

At Frankfort, where the Parseval system was permanently represented by its largest and most serviceable type (6,600 cubic meters, or 223,079 cubic feet, displacement) comparison with the "Zeppelin II" and "Zeppelin III" by visitors at the exposition could easily be made.

The virtues of the Parseval system are so obvious and simple that they can be easily understood from theory. With the Zeppelin system it has been mostly results that counted with the public. Like the Wright flyer among aeroplanes, the Zeppelin among airships has gone farthest and fastest with the lowest power and the least consumption of gasoline and oil. It has lived through the change from night to day and day to night and morning again in a single trip without stopping. It is well known how much less gas these changes in temperature and height would have meant for an airship made like an ordinary balloon. Still, compared to the Parseval, which may be said to have practically reached the pinnacle of its development, the Zeppelins may not have half realized as yet the inherent advantages of a rigid construction. They had to pay the full toll for their "extravagant" mode of handling, but did not nearly enjoy the full recompense. The Parseval is the airship of to-day, the Zeppelin that of the future.

The fundamental difference between the two systems may be stated thus: The Parseval, with its sharp distinction between "car" and "balloon," always remains a "unit," more or less. A Zeppelin, in larger sizes, becomes purely a conglomeration. A Zeppelin's weight, therefore increases at a lower rate than its lift. The "Deutschland" points the way to the giants of the future, with no cars, but a continuous "hold" and the load everywhere directly under the gas that lifts it. A Zeppelin may also have an "upper deck." It is there already; for on the uppermost "strake" a man may now safely walk from end to end after having ascended through the hull. A few thin boards and a light aluminium railing will complete it.

The Parseval ships at present are built in the dimensions given in the table.

Displacement, Cubic Meters.	Length, Meters.	Maximum Diameter, Meters.	Maximum Width Over Fins, Meters.	Maximum Height, Meters.	Car Length, Meters.	Width, Meters.	Height, Meters.	Speed, Meters a Second.	Endurance, Hours.	Height Obtainable, Meters.	Passenger Capacity.	Needed for Handling the Airship, Men.
Type A. 4,000.	60	10.4	16.0	20	0.6	1.3	1.2	13	15	2,000	6	3
Type B. 6,600.	70	12.3	17.0	22	1.0	2.0	1.4	14	20	2,500	10–12	3 or 4
Type C. 2,000.	50	8.6	14.0	18	5.5	0.8	1.1	11	8	1,000	4	1 or 2
Type D. 1,200.	40	7.7	12.0	16	5.0	0.7	1.0	9	5	600	3	2 or 3
Type E. 3,200.	60	9.4	15.0	19	7.0	1.3	1.2	10	6	1,500	6–8	1 or 2
Type F. 1,600.	45	8.2	12.5	17	5.5	1.0	1.0	8	5	600	3	.....

Types A and B have two propellers and two motors. They are so far, perhaps, the only craft completely immune from failure of the power plant.

The Rumpler Military Monoplane*

EVERYONE knows the tenacity of purpose shown by Germany in the creation of her aerial fleet, which she claims to be the finest in the world. This claim is justified in regard to unity of method, excellence of organization, and number of vessels, but not, at present, by the value of each vessel.

I say at present because Germany has not confined her construction to a particular type, but is now in her third period of evolution in aviation.

At first her principal machines, the only ones able to accomplish a few timid flights, came from French workshops, either bodily and by devious ways, or in the form of plans obtained by methods which may be guessed.

The second period was more honorable. The German aeroplanes departed from their French prototypes and assumed an individual character which was first clearly marked in the famous "Taube."

This type possesses undeniable merits, but it is not free from defects, and its performances in other countries, especially France and England, have led to its modifications in Germany. This is the third period.

Fig. 1.—Improved Rumpler "Taube" military monoplane, 1914 model. The pilot, Linnekogel, is standing on the wing.

The progress accomplished in Germany was shown in the last aerial maneuvers, but I will add the statement that the German army will possess nearly 1,500 aeroplanes at the end of the year 1914. Some of these are of the Rumpler type, which is here described.

The body, or fuselage, is trapezoidal in section, and is composed of four longitudinal members, connected by uprights and traverses, and stiffened by stays of piano wire. It rises toward the bow, where a strong frame, resting on inclined struts attached to the under carriage, supports the motor. The bow, including the pilot's compartment, is covered with sheet aluminium. The rest of the body, which tapers toward the stern, is covered with canvas.

The wings, like those of the "Taube," have nearly the form of pigeons' wings. In the original Rumpler type,

*Translated from Henri Mironet's article in *L'Aérophile*, August 1, 1914.

the wing is supported principally by a truss, the bottom chord and uprights of which are visible in the diagram (Fig. 2). Additional support is given to the wing by the front and rear beams of the wing frame. The ribs of the rigid part of the wing are made of ash, the flexible tips of corded bamboo. The wings are stiffened by interlacing wires and by stays attached to the cabane above and the undercarriage below.

The general stability of the machine is assured by the form and the flexibility of the wings. In the original Rumpler type this stability involves a certain sluggishness of control. We shall see, presently, how this defect has been removed.

The lateral stability is intrusted to the flexible wing tips. For this purpose each tip is attached to a wire, and these wires terminate in a "goose-foot" pivoted to the end of the supporting truss.

The longitudinal stability is assured by a fixed triangular horizontal plane, prolonged to form a flexible tail, which is attached and flexed similarly to the wing tips. The vertical rudder is double, and turns on a stern-post at the extremity of the body.

The landing gear is very strong; and the fuselage rests on its two principal uprights, which are reinforced by two pairs of inclined struts, of which the front pair supports the motor and the rear pair supports the rear end of the body. The two wheels turn freely on a fixed axle, provided with springs. The after part of the machine is supported, when on the ground, by a skid provided with springs and with a brake-shoe, under the control of the pilot.

Warping is effected by turning a wheel, elevation and depression by moving a lever backward and forward, horizontal steering by moving the usual transverse foot bar. The propeller is coupled directly to a fixed Mercedes motor of 100 horse-power. The reservoirs are fitted beneath the passenger's seat, and the radiators are placed on each side of the fuselage.

The sluggishness of control exhibited by this original Rumpler type is remedied in the new model (Fig. 1), in which the wings themselves are not flexible. They have flexible tips, or ailerons, however. Furthermore, the supporting truss has been done away with beneath the wings, which are made with heavy I-beam longitudinals, such as are used in most monoplanes.

The results obtained by these improvements are very satisfactory, as was proved in Linnekogel's attempt to surpass the record of height. The new type has greater horizontal and ascensional speed than the old one, and is more easily controlled. Hence, it will probably be adopted instead of the original Rumpler model.

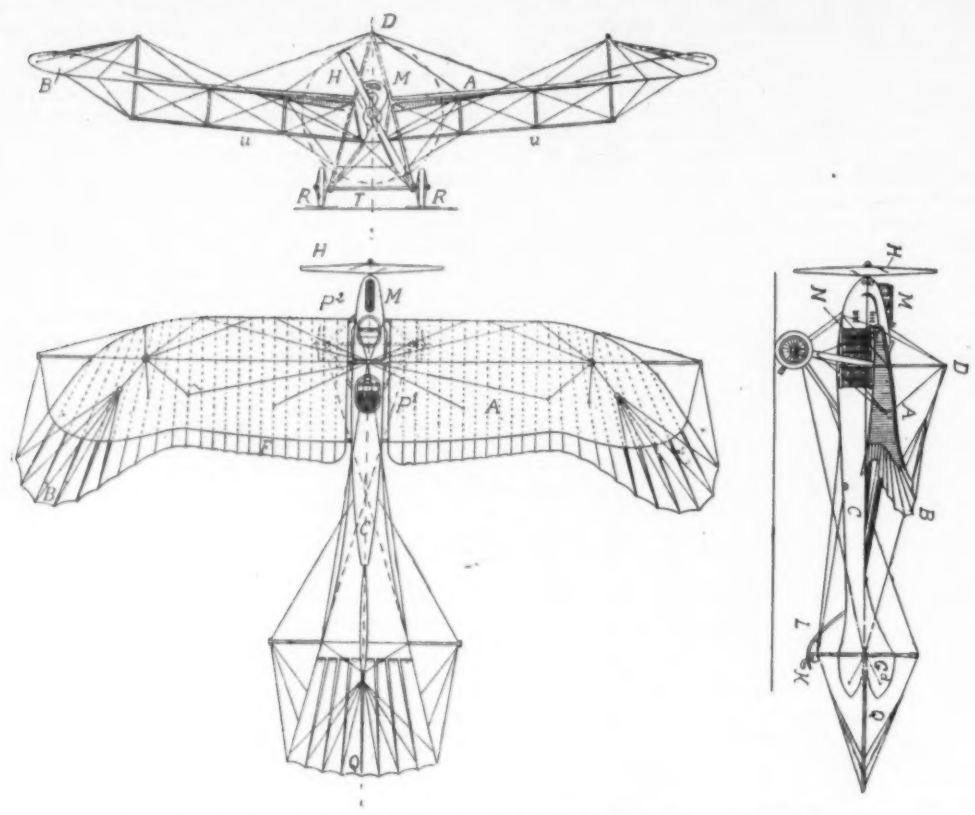


Fig. 2.—The Rumpler monoplane. Original model with flexible wing tips.

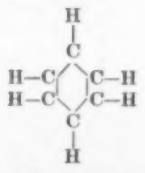
A, wing; *B*, flexible tip; *C*, fuselage; *D*, cabane; *E*, reservoir; *F*, flexible rear part of wing; *Gd*, rudder; *H*, propeller; *K*, brake shoe; *L*, skid; *M*, motor; *N*, radiator; P^2, pilot; P^1, passenger; *Q*, flexible elevator; *R*, landing wheels; *S*, foot tiller; *T*, axle of landing gear; *U*, wing truss; *V*, warping wheel and elevating lever.

Coal Tar Products in Medical Use

A Review of the Important Developments of an Extensive Class of Compounds

THERE has been a good deal of discussion, during these days of the European war, regarding the coal tar product industries which have reached such a wonderfully flourishing condition in Germany. The center of interest has perhaps been taken up by the dyestuffs industry, which has received its share of attention by us on another page. Another phase of the coal tar industry, the application for medical purposes of various products derived from the dry-distillation of coal and allied substances, is discussed by Dr. Georg Wolff in the German periodical *Technische Monatshefte*.

The writer points out that the important developments in the medical employment of coal tar products date from the time of the discovery of antiseptic and aseptic methods in medicine and surgery, with which the names of Lister and Pasteur are so gloriously linked. For among the coal tar distillates are found some of the chief of our modern antiseptics and disinfectants. Perhaps the first substance of this class which occurs to the mind of the layman is carbolic acid, or as it is called in more strictly technical language, phenol. It may be well to give the reader some idea of the general type which characterizes from a chemical point of view, a numerous class of substances derived from coal tar, and known to the chemist as aromatic or benzene compounds. Phenol is a typical example of this class, being very closely related to the fundamental substance, benzene. This latter is a compound of carbon and hydrogen, containing six atoms of each in the molecule, so that its formula C_6H_6. For reasons which cannot be explained here, the chemist regards the six carbon atoms of this molecule as being linked together in the form of a hexagon, each carbon atom having a hydrogen atom attached to it after the manner shown below.



Each of the hydrogen atoms is capable of being replaced by a great variety of elements or combination of elements, and thus a vast number of so-called benzene derivatives are obtained. One of the simplest of these is phenol or carbolic acid already mentioned. It differs from benzene in that one of the hydrogen atoms is replaced by the hydroxyl or OH group, which is formed of one atom of oxygen and one atom of hydrogen. There are also substances known as cresols, which contain, in addition to the hydroxyl group, the so-called *methyl* group, CH_3. There are three of these, as the hydroxyl and methyl groups may be attached to adjacent carbon atoms in the hexagonal benzene nucleus, or two alternate carbon atoms, or yet again to two diametrically situated carbon atoms. These three cresols are distinguished in chemical terminology as respectively ortho, meta, and para cresols. We shall have occasion to refer to them again later.

As regards coal tar itself, Dr. Wolff remarks that this does not, to-day, find much use in medicine. He goes on to say: "Somewhat more generally employed are certain kinds of wood tar made by the dry distillation of the wood of juniper, beech, birch and fir. While coal tar is alkaline in reaction owing to the presence of ammonia and allied bases, the wood tars are acid in reaction, owing to the presence of acetic (pyroligneous) acid and its allies. These wood tars are also rich in phenols and aromatic hydrocarbons. Wood tars have long been used in treating skin diseases. Of recent years they have largely been displaced by coal tar products, such as naphthene, resorcinol, ichthyol, etc., concerning some of which more will be said presently. There is still a third kind of tar, which in the past has found use in medicine, namely so-called animal tar, prepared by distilling various waste products such as bones, horns, hoofs, etc. This highly malodorous product used to be prescribed as a remedy for asthma. Fortunately, better and less repulsive medicaments are known to modern medicine.

"A distant relative of animal tar is the ichthyol of which mention has just been made. This is obtained by the dry distillation of bituminous shale containing fossil fish remains. The ammonium salt of the oil, after treatment with sulphuric acid, contains 10 per cent of sulphur and is much valued in combating such skin disorders as eczema. Now the fossiliferous shales are unfortunately scarce and efforts have therefore been made to prepare an artificial substitute for ichthyol. By treating coal tar products with sulphur at a high temperature the substance known as thiol is obtained, which has found somewhat similar use as ichthyol. Tar sulphur soaps owe their efficacy partly to the disinfecting qualities of the tar, and partly to its property of causing the skin to scab off. There may also be a slight local anesthetic action which relieves itching."

Passing from the consideration of the comparatively crude coal tar products, Dr. Wolff then goes on to the discussion of a class of definite chemical compounds, some of which are isolated from coal tar by distillation, while others are prepared by definite chemical processes.

"Among these are the phenols already mentioned and such substances as salicylic acid, benzoic acid and others. As regards the action of these upon the human organism, certain general statements can be made. They are antiseptic, as already noted, that is to say, they tend to arrest the growth of bacteria, and what is more important, they have this effect upon bacteria without at the same time equally injuring the human organism. They are also antipyretic, that is to say they reduce the temperature in fever cases. This is especially true of salicylic acid. A peculiarity of the benzene derivatives which contain the hexagonal nucleus spoken of above, is that they pass through the body with that nucleus unbroken, that is to say they are not, like most carbon compounds taken in with the food for example, oxidized completely to carbon dioxide and water.

"Benzene itself, the parent substance of the aromatic compounds, finds little use in medicine. Its near ally, naphthalene, which is built up of two hexagonal nuclei linked together, has the peculiarity of being highly poisonous for lower animals, while being comparatively harmless to man. For this reason it is a familiar household remedy against insects, moths, etc., and has also a field of usefulness in medicine in dealing with parasitic troubles.

"The simplest phenol, that known in the trade as carbolic acid, is not now used quite as extensively as in former days. It used to be the regular standby of the physician in the operating room. While its use for applications of this character has not ceased entirely, it now finds its principal employment for cruder purposes of disinfection, and the cresols have in a measure supplanted phenol as an antiseptic.

"Among the cresol preparations, a drug known as Lysol is particularly valuable. It is made from equal parts of cresols and soft potash soap. The addition of the soap merely serves the purpose of making the cresols

soluble in water. Without such addition they are only very slightly soluble. The cresols, which differ from phenol by the addition of a methyl or CH_3 group, as has been explained above, have the advantage of being somewhat stronger antiseptics, and at the same time less poisonous than phenols. Nevertheless they are not entirely non-poisonous, and unfortunately cases are on record of Lysol having been used by suicides.

"There are also phenols containing two or more OH groups attached to the benzene nucleus. Thus, for instance, the well-known photographic developer hydroquinone is para-hydroxy-benzene, that is to say it is derived from benzene by the substitution of two diametrically opposed hydroxyl groups in the hexagonal nucleus. This substance is not used in medicine, but its close ally resorcinol, the corresponding meta-compound, is used in the treatment of skin diseases owing to its solvent action upon the skin. Another drug used for similar purposes is the tri-hydroxy-benzene known as pyrogallol or pyrogallic acid to photographers. The hydroxy compound of naphthalene also, naphthol, is used as a medicament for the skin. To be quite exact there are two naphthols, distinguished as alpha and beta naphthol, which differ in the position of the hydroxy group in the naphthalene nucleus, and only the latter of these two finds medical application. It has to be used with some caution as it has a peculiar property of being very readily absorbed by the skin, and if used in too large doses it is apt to unfavorably affect the kidneys.

"Another important tar product is creosote, which is not a single chemical individual, but consists chiefly of guaiacol and creosol, compounds of rather more complicated structure than the phenols. Creosote resembles in its action the phenols, but has been found adapted to internal use, and forms one of the stock remedies in the treatment of consumption. It was at first supposed that it exerted some degree of germicidal action upon the tubercle bacilli. This view is hardly held by any authority to-day, although creosote does seem to exercise beneficial action in cases of tuberculosis, probably owing to secondary causes.

"Of the simple acids closely allied to benzene we may mention three as of medical importance. Benzoic acid, structurally the simplest of all aromatic acids, used to be administered in cases of gout. This use is practically discontinued at the present day, and benzoic acid is now prescribed only as an expectorant in bronchial catarrhs and similar affections.

"A more complicated acid is cinnamic acid, closely allied to the characteristic ingredient of cinnamon. Of late, this has been prescribed against consumption. It is also the essential ingredient of Peru balsam which is used in contending with some very disagreeable skin parasites.

"The most important, however, of the simpler acid derivatives of benzene is salicylic acid, which is closely related to benzoic acid, differing from it by the presence of a hydroxyl group attached to the benzene nucleus. Salicylic acid owes its name to the source from which it was first derived, namely willow bark, the Latin name for willow being *salix*. Willow bark has been known from antiquity as a febrifuge. Salicylic acid has three medically useful properties. Like most of the compounds of its class it is antiseptic in its property, and lowers the body temperature. In addition to this it has been found a very excellent drug for the treatment of acute rheumatism of the joints. By combination with other substances, salicylic acid has been made the source of numerous other products, of which only one or two shall be mentioned here. The substance known as salol is a combination of salicylic acid with phenol. A compound of salicylic acid with acetic acid is known as asperin, a household remedy for headaches, rheumatic pains, etc."

Following Dr. Wolff, we have here taken a brief survey only of some of the simpler coal tar products which have found a place in the doctor's medicine chest. The industry of synthetic medicine has in recent years been developed with great skill and with much success. To give an adequate presentation of what has been accomplished in this field would, however, require the introduction of complicated formulas and uncouth technical terms, such as delight the organic chemist. We shall therefore rest content with this survey of the simpler coal tar products employed in medicine.

Honoring Napier

On July 24th a celebration was held at Edinburgh in honor of John Napier, the inventor of logarithms, and the following notes on the occasion, and from the remarks of the speakers, are from a recent issue of *Engineering*, London.

Three hundred years ago there appeared a small quarto volume, "Mirifici Logarithmorum Canonis Descriptio," whose influence upon the development of mathematics it is difficult to overestimate. It was the first set of logarithm tables, and was the evidence of a new thought and a new power, destined to revolutionize arithmetical calculations.

In teaching his generation how to construct tables of logarithms, he devised an artifice that with accuracy and facility solves a number of problems that previously could be dealt with only by the expenditure of much time and the cumbrous method of simple arithmetic. It was a great achievement, only possible to a profound thinker; but it is so easy to turn up a table of logarithms that we forget the labor involved in forming the first. We appreciate as little the industry and patience needed as we do the clearness of thinking and the training required to take a new step in a direction in which there are no pioneers.

Though logarithms figure mostly as an instrument for facilitating calculation, that is not the form in which the problem presented itself to the inventor. A far more general principle engaged his attention. He sought to determine the motion of a point which moved in a straight line with varying velocity, the velocity being proportional to the distance of the moving point from a given point. He asked what was the length of the line passed over in each case in equal increments of time, and in that way was led to perceive the relation between two series of numbers—one increasing in arithmetic progression, the other in geometric. Doubtless to Napier there appeared no other way of approaching the subject. But there are widely different methods of arriving at the same truths; for in mathematics, more often than in other branches of science, it has been shown that results which seemed so remote and concealed that they could only be successfully attacked in a certain direction, prove to be singularly simple when viewed from another standpoint.

The principal address was made by Lord Moulton, himself a distinguished mathematician, who devoted himself in his remarks rather to an analysis of Napier and his methods. Every fact known about Napier, said Lord Moulton, had become commonplace. They were all aware when he was born and when he died; that he wrote at length on the Apocalypse; that he was suspected of trafficking in black magic, etc. What was known left the man very imperfectly disclosed, but sufficed to show him strong and self-reliant, of solitary habits, and of profound and untiring industry.

There was, however, one aspect, as it appeared to Lord Moulton, in which he might perhaps find something to contribute, even though it should prove but a widow's mite. The invention of logarithms came on the world as a bolt from the blue. No previous work had led up to it; nothing had foreshadowed it or heralded its arrival. Did this come as a revelation to Napier, bursting upon him as a light from heaven, or was it the result of a slow growth, the evidences of which were now obliterated? The undoubted fact is that Napier worked for some twenty years at logarithms before he published his first book relating to them. It must have been a slow and gradual evolution, even though that which remained furnished so few traces of the earlier efforts. Was it then possible from the records left, and out of the circumstances of the time, to read the history of this evolution, to reconstitute the process of discovery by deciphering the half-effaced records of this growth? It was in this direction that something of interest might be found.

Lord Moulton then proceeded to discuss the question, What set Napier to work on the lines he did, seeing that there was no antecedent work to suggest a plan, and to indicate what were probably the different stages of the discovery? It was urged with increasing probability that Napier, seeing that trigonometrical tables enables a product to be found without actual multiplication, conceived the idea of constructing special tables which would do the same work in a more thorough and expeditious manner; it was probable that originally Napier contemplated nothing further than repeated multiplication by a factor near to unity, so that each multiplication reduced, very slightly, the number operated upon, and that the word "logarithm," signifying "the number of the ratio," preserved that idea. In the second stage of the discovery, the notion of multiplying by a factor gradually gave way to the idea of taking an aliquot part from the number arrived at by the preceding operation, and that this thought led Napier to pass from the idea of figures to the geometrical representation of the quantity by a line, and to find that his repeated operations were perfectly repeated by cutting off the same fraction of the same diminished length. Further, that at this stage Napier took the simple and obvious step which ultimately proved of momentous importance, completing his discovery, and putting him in a position to commence the calculation of tables.

Another speaker who addressed the meeting was Dr. J. W. L. Glaisher, who contended that, as a product of the time, the conception of logarithms in Napier's mind was little short of marvelous. He had no notation such as they had now to guide him, and in mathematical development a good notation was of primary importance. As regards arithmetic notation, it would appear that Napier was the first to use the "point" in expressing decimal fractions, a notation far superior to that devised by Stevinus, and widely used even in Napier's day. The more they examined the method of Napier the more were they impressed by his greatness.

Prof. Eugene Smith of New York read a paper on "The Law of Exponents," as illustrated in the works of the XVI century. The nature of the geometrical progression and its correspondence with a parallel arithmetic progression was traced through the works of Chuquet, 1484, and Boethius, 1499, to the writings of Rusdolif, 1525, and Stifel, 1544, to those of a later date. It was this line of development which influenced Burgi, whose "Progress Tabulen" contained what was an antilogarithmic table. The importance of these arithmetical relationships, clearly conceived by the Teutonic school, was recognized by Cardan. These relationships approach so closely the idea of the logarithm, that it was a cause for wonder that the works of Napier and Briggs were not anticipated.

Remarkable Deflections of the Plumb Line in Northern India

Deflections of the plumb line of a remarkable character have been discovered at points near the southern border of the Himalayas, and these are considered by R. D. Oldham in the Royal Society *Proceedings* and the geological structure of the region is discussed. The known geodetic facts are that along the southern edge of the Himalayas very high northerly deflections, amounting to about 40 seconds of arc, are found, which rapidly decrease in a southerly direction by about 30 seconds in as many miles, after which they become much more gradual. Northerly also there is a decrease, though not so rapid as to the south. Burrard's hypothesis, in explanation of these facts, is the existence of a belt of deficient density, of considerable depth, but of no great width, along the southern edge of the Himalayas. As this rift is on a scale of magnitude far in excess of anything for which there is geological precedent, the author has been led to investigate whether some other explanation was possible more in accordance with geological observations. The geological structure is as follows: Along the southern edge there is a great fault separating the older rocks of the range from the upper tertiary, Siwalik beds, which Medlicott showed to have been formed under conditions similar to those of the recent deposits in the Gangetic depression, and to be the lower, marginal deposits of the same continuous formation, of which the Gangetic alluvium forms the uppermost members. The depth of this formation along the northern margin is certainly great, nowhere less than 10,000 feet, and possibly 30,000 feet in places. On the southern margin the thickness is small, and the deposit thins out over an old land surface of rock. Between these two limits it is natural to suppose that the depth of the alluvium decreases gradually from north to south, and its mean density has been taken at 2.1, the mean density of the rock forming the sides and floor of the depression being about 2.7. It is the effect of this large bulk of material, having a density of only about seven ninths of the average density of surface rock, which has been investigated. The method adopted was based on Hayford's system of compartments, the trough being assumed to run east and west, with the deep side on the north, and divided into belts of ten miles wide, running parallel to the margins, in each of which the depth was assumed to be uniform and equal to the mean depth of the belt. The data obtained are subjected to the necessary corrections, and the general conclusions to be drawn appear twofold: (1) that the local deflections of the plumb-line, produced by underground topography, along the region bordering the southern margin of the Himalayas, are of such magnitude as to make the observations, at stations situated in that region, of small geodetic value, unless allowance is made for the invisible, as well as the visible, topography; and (2) that there is no geodetic justification for the assumption of the existence of a deep and narrow rift, filled with material of lesser density than the rock on either side, or for any modification of the deductions, regarding the form of the floor of the Gangetic depression, which have been drawn from geological observation.

Agronomic Institute.—The National Agronomic Institute of France, which is located at Paris in the University quarter, is at present in a flourishing condition, this being evidenced by the considerable extension which is being made to the building, and it will be at least doubled in space. The new portion is expected to be completed in the near future, and like the former it will house various laboratories and other quarters connected with agronomic work. Prof. Regnard, an eminent scientist, is at present at the head of the institution.

The Physiological Standardization of Drugs

How the Strength of Drugs is Determined and the Proper Dose Found

By Lewis Davis, M. S.

It is a curious fact that, to the average person, all medicinal agents are shrouded in a veil of mystery. Take the term "drug," for example, and it unconsciously brings to the lay mind the childhood conception of the simmering pot in the deep wood filled with strange roots and herbs, and attended by the witch with her peaked hat and crooked staff. Only to such hardy adventurers as the physician and the pharmacist has been left the task of penetrating this maze. The ordinary mortal is content to escape by heroically taking doses of bitter-tasting "medicines" in his illness, or stoically submitting to hypodermic injections, regardless of the origin or value of the material employed.

Fortunately, science does not share in this attitude. Careful investigation has not only succeeded in establishing the composition and therapeutic action of many drugs, but has set up certain standards of activity to which they must conform. The modern physician no longer prescribes drugs, trusting to good fortune that they contain a requisite amount of active principle. These have all been assayed in the laboratory by their actions on test animals with a degree of delicacy far surpassing the most refined chemical or physical means. When it is considered that 0.00002 gramme of the active principle of Strophanthus seeds will cause the death of a test frog weighing one million times that amount (20 grammes), the extreme sensitiveness required of a suitable method of standardization is readily apparent. In fact, chemical methods of testing are not only by far incapable of such extreme delicacy, but are more usually of no value.

It might be well to ask, what are these substances—drugs—which are so highly potent in their effects? A popular definition of a "drug" might be given as any substance—animal, vegetable, or mineral—used in the preparation of medicine, or in the cure of disease. This would include chemicals, the alkaloids, vaccines, serums, certain gland products, and finally, those plant substances of undetermined chemical nature which are capable, upon introduction into the body, of producing certain distinct effects. Properly speaking, it is these last two products—the gland materials and plant derivatives—which should be designated as "drugs."

While the plant derivatives, particularly the heart tonics, have been known to the scientific world for decades, our knowledge of the gland products and their actions has all come to us within the past fifteen years. Two of these, in particular, command our attention—products from the suprarenal gland and those from the pituitary gland.

Surmounting each kidney usually, or lying very close to it, we find the right and left adrenal glands, the latter being usually the larger. They differ in shape from each other, and the right capsule having a flattened triangular form, the left a crescent shape. There are also variations from these forms. In the human they weigh about four grammes and are nearly as large at birth as in adult life. In color they are dark red, or sometimes yellowish red. One or both capsules may be absent, although this is rarely the case.

The glands are smaller in advanced age, and it is said that negroes have larger ones than Caucasians, which fact no doubt bears some relation to the pigmentation of the skin.

When sectioned, they are seen to consist principally of two parts, an outer firm portion (cortical), and an inner (medullary) part which is soft and pulpy. These parts are usually quite definitely marked, but it is difficult to separate them perfectly since they are more or less closely "dove-tailed" into each other.

Removal of the suprarenal bodies in animals is speedily followed by symptoms of extreme muscular prostration and within a few days by death. For years a puzzle to the physiologist and physician, it came as a surprising discovery that some of the constituents of the suprarenal

Fig. 1.—Foxglove.

Fig. 2.—Ergot in rye. Fig. 2a.—Indian and American Hemp.

Fig. 3.—Lily-of-the-valley.

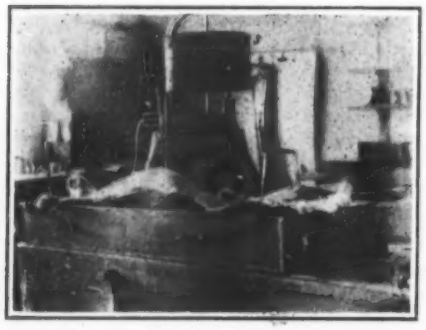


Fig. 5.—Dog connected with kymograph as used in assaying adrenalin and pituitary extracts.

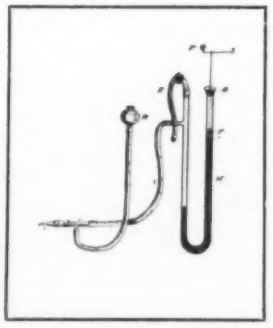


Fig. 5a.—Recording mercury manometer and canule.

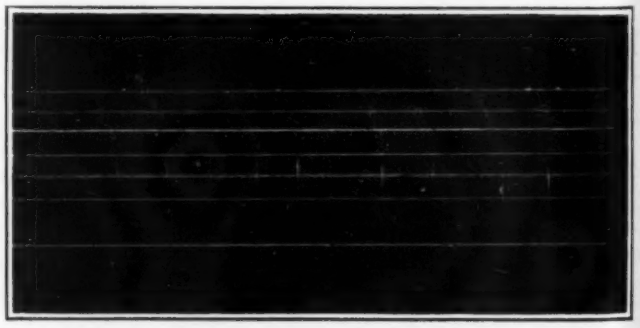


Fig. 8.—Tracing made by the kymograph, showing rise and fall of blood pressure, due to adrenalin chloride solution.

Fig. 10.—Tracings obtained with kymographion of Fig. 2 in testing unknown samples.

Fig. 4.—Dog showing characteristic intoxication of cannabis.

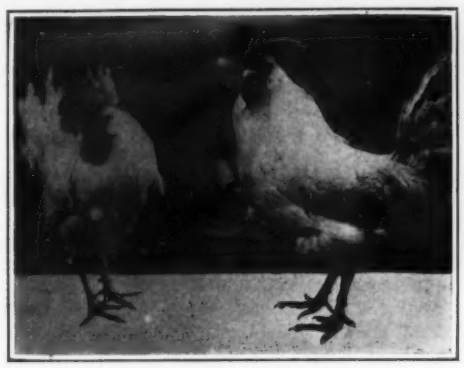


Fig. 6.—Roosters used in testing strength of ergot.

Fig. 7.—Testing the strengths of the heart tonics by their actions on frogs.

gland had a remarkable influence upon blood pressure. Few discoveries in medicine have been of greater importance than the announcement in 1897, that the suprarenal gland contained a certain substance which had the wonderful power of lessening, or even preventing, hemorrhage by virtue of its local or constricting action on the blood vessels. In other words, here is an agent at the command of the physician which diminishes the flow of blood by simply, so to speak, "stopping it up." As would be expected, extracts and various products of this gland soon came into use for producing bloodless operations in eye and other delicate branches of surgery, for the prevention of hemorrhage, and for increasing the blood pressure. Careful scientific investigation has resulted not only in the preparation of the active constituent of the gland in a chemically pure form, but more recently a synthetic product has come upon the market, identical in all its remarkable properties with the natural product obtained from beef.

The natural material, known under various names, as "adrenalin," "suprarenin," etc., is, when pure, practically white in color, and composed of microscopic crystals of various forms. These chemically pure crystals (of "adrenalin") serve as a standard for the assay of products of the suprarenal glands, and the strength of any product is stated in terms of the standard—as, for example, "Solution of Adrenalin" 1–10,000, etc.

Although very recently a chemical method has been proposed for the assay of adrenalin and similar products, the physiological method is used almost entirely. Various animals may be used for this purpose, but the best results are obtained with medium-sized dogs.

The physiological determination of the strength of products from the suprarenal and of the pituitary glands —these latter substances will be discussed later—is almost identical. The method depends upon the fact that when properly diluted doses of these drugs are injected directly into the circulatory system of test animals (dogs) there is produced a definite, characteristic rise in the blood pressure of the animal which soon comes back to normal. The test animal is first anæsthetized completely, after which the hair is clipped from the throat and the tissues severed. A glass "cannula," as it is called, or connecting tube of suitable size is now tied in the common carotid artery, which, in turn, is connected with a tube filled with sodium carbonate (soda ash) or other solution, to prevent the blood from clotting. The latter tube is attached to a manometer or "U" tube containing mercury. A schematic representation of a recording mercury manometer and its connection with the artery is shown in Fig. 5a. *C* represents the "cannula" which is inserted in the artery previously clamped. On releasing the clamp, the pressure of the blood is communicated through the liquid in *t* to the column of mercury in the manometer *M*, until the weight of the column which is forced up, shown by the difference in level between 1 and 2 counterbalances the pressure of the blood. The limb of the U tube in which the mercury rises carries a float (*f*) of aluminium, hard rubber, or some other substance lighter than the mercury. This float, in turn, carries a stiff wire which plays through an opening in the cap (*G*) of the tube. The free end of this wire bears a needle (*P*) or more usually a bent metal arm, which marks a tracing on a revolving sheet *S*. The latter may be plain, white, or sensitized paper, but is more often smoked paper, and the record scratched out by the metal pen.

Such a complete recording apparatus, known as the "kymographion," and its connections to the test dog are shown in Fig. 5, as used in a large commercial laboratory for the routine standardization of products from the suprarenal and pituitary glands. The method, in brief, is as follows:

A definite quantity of the standard solution is injected into the femoral vein (Fig. 5), and with the kymographion in motion, the maximum rise in blood pressure is communicated through the tube *t* and recorded on the revolving sheet (*s*). The pressure is now allowed to return to normal, after which, varying amounts of the solution are similarly injected until the resultant increase of pressure as recorded by the needle is equal to that produced by the known amount of the standard. For example, if it takes three cubic centimeters of the unknown to produce the same rise in blood pressure as that caused by one cubic centimeter of the standard, then the sample is said to be "33⅓ per cent of standard," etc. A tracing of this sort is shown in Fig. 10, while Fig. 8 shows the sudden rise and slow return of pressure due to an injection of adrenalin chloride (1 in 100,000 parts).

As already mentioned, the usual method of standardizing extracts of the pituitary gland is identical with that described for adrenalin. The pituitary body or "hypophysis cereberi" as it is scientifically termed, is even a greater mystery than the suprarenal glands.

Hidden away in the very middle of the skull in a little bony cup (sella turcica), better protected than any other gland in the body, and very inaccessible, is the little body known to anatomists as the pituitary body, believed for

Fig. 9.—View of laboratory fitted for drug standardization.

a long time, until 1886, to be void of all physiological value, in fact, a sort of useless appendix of the brain. Some of the older writers ascribed to it the function of secreting mucus, hence the term "pituitary body"; others ascribe to it manifold functions. In the human and in sheep it weighs about 0.5 grammes, in cattle 2.5 to 3 grammes. In shape it is oval, and when fresh it has a pinkish color.

If we were to section the pituitary gland, we would see plainly two definitely marked parts, but histologists tell us that it is composed of three parts—anterior, posterior and intermediate. It is usually described as consisting of two parts—the larger or "anterior lobe," and the much smaller "posterior lobe." The "posterior lobe" arises as an outgrowth from the floor of the brain and it is this portion which contains physiologically active substances of considerable therapeutic importance. The active principle, known as "pituitrin," "hypophysin," etc., also has the power of raising the blood pressure similar to that of adrenalin, but to a more marked degree. In addition, it has the remarkable property of causing contractions of the uterus, and within the last few years has come to be of great assistance during child-birth, in cases of uterine insufficiency. The drug has also the power of stimulating the secretion of urine and especially of milk.

Disturbance of the pituitary due to disease or otherwise may bring about the conditions known as "acromegaly" and "gigantism." In the former case there is an enlargement of the bones of the face and extremities, while in the latter there is an overgrowth in the whole skeleton.

Both in pituitrin, but particularly so in adrenalin, there is a more or less clearly defined active principle upon which the physiologic assay can be based. There are, however, two very important drugs which have no such constituent that can be utilized to base a method upon. These are ergot and cannabis.

Under certain conditions rye may become affected with a black smut or fungus growth which is known as the "ergot" of rye (Fig. 2). Almost all of the ergot of commerce comes from Russia and Siberia. Aside from its use to stimulate the heart and to increase the blood pressure, the alcoholic (fluid) extract of the drug is employed to assist contractions of the uterus in child-birth in the same way as pituitrin.

Considerable research on the subject has failed to bring about any agreement as to the active principle or principles of the drug. Blood pressure experiments gave too variable results to be relied upon, while its contraction of the muscle of the uterus also proved unreliable. Not baffled by this, the pharmacologist has cast about and found the desired subject in our shrill announcer of the dawn—the rooster. The physiological testing of ergot depends upon a characteristic blackening or blanching which it produces in the comb and wattles of selected cocks, when the drug or its preparations are internally administered in suitably sized doses.

The test fowls are normal, thoroughbred, white Leghorn cocks, twelve to eighteen months old, which have been allowed to fast for twenty-four hours. The animals should not be used for a longer period than six months, and not oftener than once a month. The standard used is a fluid extract of the drug, made up according to the "U. S. Pharmacopœia," and which by repeated tests has been shown to possess the average activity of, at least, ten samples of first class, commercial ergot. The alcohol in both the standard and the unknown samples is removed by evaporation. and both converted into as nearly the same condition as possible. The alcohol-free samples were formerly introduced into the crops of several of the test fowls through a soft rubber tube in doses of 15 cubic centimeters per kilo of body weight. Now, however, it is more usual to inject a smaller dose directly into the breast muscle. By varying the size of dose and repeated trials, the amount of the unknown is determined which will produce the same degree of blackening in the parts as the test dose of the standard. (See Fig. 6.)

Very rarely is intoxication induced for such a worthy purpose as in the standardization of cannabis. "Cannabis Sativa," or, as it is better known, "Indian Hemp," is extensively employed in the treatment of insomnia, neuralgia, headache and hysteria. The dried, flowering tops of the plant are used, and careful investigation has shown the domestic variety of the drug, "American Hemp," to be fully as efficient as the imported product from India.

The active constituents of Cannabis are even less understood than in the case of ergot, consequently chemical standardization is out of the question. Here again, a physiological method is made use of. with healthy, medium-sized, short-haired dogs, young, but full grown, as the test animals. The standard used is a U. S. Pharmacopœia extract of cannabis having the average activity of not less than ten samples of first-class, commercial drugs, and the standard test dose is 0.010 gramme per kilo body weight.

In testing, at least two dogs, susceptible to the drug, are used, one of which receives the standard, and the other the unknown sample. These are administered internally in a small capsule by drawing the dog's tongue forward between the teeth with the left hand, and placing the capsule on the back part of the tongue with the right hand. On quickly releasing the tongue, the capsule is swallowed with ease. To aid in absorbing the drug, the dogs are usually allowed to fast for twenty-four hours before the test.

Active extracts when administered to susceptible animals show three typical effects: First, excitability, then a period of incoördination, followed finally by drowsiness. The second stage of incoördination usually follows in one to two hours; the animal loses control of its legs and of the muscles supporting its head. If nothing occurs to attract the dog's attention, which is absolutely essential, the head will drop, the body sway, and when severely affected, the animal will stagger and fall, the intoxication being peculiarly suggestive and striking. (See Fig. 4.)

The influence of the test dose of the unknown drug is carefully compared with the same dose of the standard administered to another test dog at the same time and

under the same conditions. When the animals become droway, the observations are recorded and the second day following, the two dogs are reversed. The animal previously receiving the test dose of the unknown now receives the test dose of the known, and *vice versa*, a second observation being made. From the dose of the unknown, selected as producing the same action as the test dose of the standard, the amount of dilution or concentration that is necessary is determined.

It would hardly occur to the average reader that aside from its epicurean possibilities the frog forms one of the most delicate testing instruments at the disposal of the scientist. Yet it is an actuality that only by careful tests on frogs is it possible to assay the strength of those drugs known as the "heart tonics of the Digitalis Series." These drugs, of which the lily of the valley or convallaria, the fox-glove or digitalis, squill and strophanthus are the most important members, have a special affinity for the heart muscle tissues and are very active poisons. The active principles of all of the drugs are so very much alike that they may be considered as one group and may be physiologically assayed by the same method. They differ greatly, however, in the amount of their activity and in their poisoning powers. It is precisely this poisoning power, particularly with cold-blooded animals, which is made use of in determining the strength of these drugs. Briefly, the method of administering these poisons and of observing results is as follows: (Fig. 7.)

The drug, or its tincture, is dissolved in salt solution of the same strength as that found in the body fluids. By means of long, slender, glass measuring tubes or "pipettes," having a hypodermic needle attached, accurately measured amounts are now injected directly through the frog's mouth into the abdominal lymph sac.

As a rule, it is necessary to inject several series of about five frogs each for each sample of the drug to be tested. The first series is injected with a standard tincture of strophanthus made up according to the U. S. Pharmacopœia. Usually 0.00015 cubic centimeter per gramme body weight of frog is found to be the smallest amount of this drug which kills the frog, or, as it is known, its "minimum fatal dose" (M. F. D.). The second series is now injected with doses of the unknown varying considerably in size.

After the approximate dose of the poison has been found from the second series, a third series is injected to fix the minimum fatal dose. Finally, a fourth series is injected which fixes the limits of strength very closely. In a good test, the minimum fatal dose in the fourth series should kill at least three frogs out of five. Now, by comparing the minimum fatal dose of the standard with that of the unknown, a certain ratio is obtained, as 1¾, ⅔, etc.

It is usual to express the strength of this series of drugs in terms of "heart tonic units" (H. T. U.), the heart tonic unit being ten times the minimum fatal dose per gramme body weight of the frog. The standard tincture of strophanthus has been found to contain 650 heart tonic units. To give the strength of the unknown drug, all that is necessary then is to multiply the above ratio of the minimum fatal doses by 650 to get the number of H. T. U.'S (heart tonic units) the drug contains in every cubic centimeter.

Heat; A Lecture for Beginners*

An Explanation of Terms and Principles Necessary to Understand Engineering Problems

By Charles H. Bromley

As the boiler is a combined heat generator and heat absorber, an understanding of what the unit of heat is, is essential to a thorough understanding of boiler operation. Heat is a form of energy for which there are numerous explanations, but they are of little practical value to the power-plant man. One of the most essential things for him to know is that the standard quantity or unit of heat in general use in this country is the *British thermal unit* (abbreviated B.t.u.). In practice, this *quantity* is usually considered as that amount of heat required to raise *temperature* of water 1 deg. Fahr.

TEMPERATURE.

While the B.t.u. is the *quantity* of heat, the temperature indicates the *quality* of heat. One hundred pounds of water at 100 deg. Fahr. contains more heat than one pound of water at 200 degrees. One body of water is twice as *hot* as the other, but it did not take as much heat to make it that hot as it did to make the larger body one half as hot; see Fig. 1. Remember that temperature indicates only *how hot* a body is; it does not tell directly *how much heat* there is in it.

which water freezes at 32 degrees and boils at 212; the *Centigrade*, used universally, on which the freezing point is 0 degree and the boiling point 100, and the *Reaumur*, where the freezing point is 0 degree and the boiling point 80 degrees. We see then that

1 deg. Fahr. = $\frac{5}{9}$ deg. Cent.
1 deg. Fahr. = $\frac{4}{9}$ deg. Reaumur,

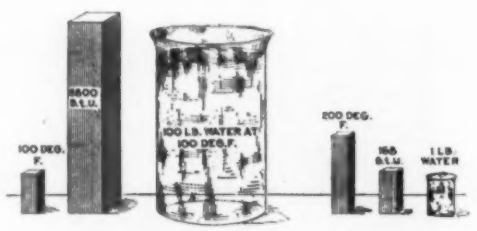


Fig. 1.—Showing that temperature is not alone a direct indication of the amount of heat in a body.

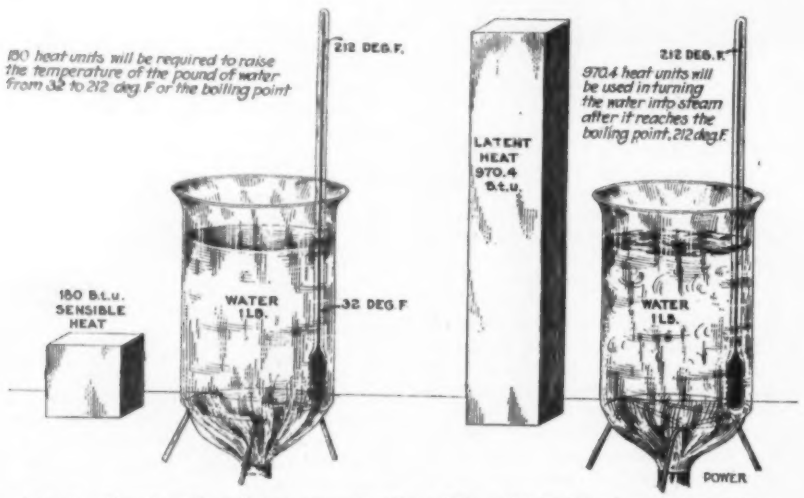

180 heat units will be required to raise the temperature of the pound of water from 32 to 212 deg. F or the boiling point
212 DEG. F.
180 B.t.u. SENSIBLE HEAT
WATER 1 LB.
32 DEG. F
LATENT HEAT 970.4 B.t.u.
212 DEG. F.
970.4 heat units will be used in turning the water into steam after it reaches the boiling point, 212 deg. F.
WATER 1 LB.
POWER

Fig. 2.—Showing the relative amounts of sensible and latent heat needed to boil a pound of water into steam at atmospheric pressure.

Pressure, of course, has a good deal to do with heat and temperature as related to water. For instance, as seen from Fig. 1, there is much more heat in the 100 pounds of water at 100 deg Fahr. than there is in the one pound of water which is at 200 deg. Fahr. Suppose we had the one pound of water under 400 pounds absolute pressure, that is, the pressure as indicated by the gage plus the pressure of the atmosphere or 15 pounds; the temperature would be 444.8 deg. Fahr. The one pound of water would contain 1,208 B.t.u. at this temperature—over seven times as much as when heated to 200 deg. Fahr.

THERMOMETER SCALES.

The measurements of temperature as we make them are arbitrary. They are made to suit our convenience, as shown by the three standards in use; the *Fahrenheit* scale, which is mostly used in engineering calculations in America, and the British Isles, and according to

* Reproduced from *Power*.

so that to express the different scales in terms of one another we have:

Fahrenheit degrees — 32 × $\frac{5}{9}$ = Centigrade degrees.
Fahrenheit degrees — 32 × $\frac{4}{9}$ = Reaumur degrees.
Centigrade degrees × $\frac{9}{5}$ + 32 = Fahrenheit degrees.
Reaumur degrees × $\frac{9}{4}$ + 32 = Fahrenheit degrees.

ABSOLUTE TEMPERATURE.

Put a cake of ice in a room where the temperature is 20 degrees below zero and the ice will eventually cool *off* until its temperature is the same as that of the room; the ice will *give up heat* to the air in the room. We see then that, although ice forms at zero degrees on the Centigrade scale, this is not the lowest temperature that a body may attain; it is not the temperature at which there is a *total absence of heat*, not *absolute zero* beyond which it is impossible to cool a body. Neither are the zero points on other thermometers; man puts them where it is convenient, but the absolute zero of temperature is not fixed by man, Nature having established it for man to discover.

Experiments on the expansion of gases kept at a constant pressure show that the volumes and temperatures increase and decrease proportionately; the volume increasing $\frac{1}{273}$ for each degree Centigrade increase in temperature and decreasing $\frac{1}{273}$ for each degree Centigrade decrease in temperature.

This being so, we see that, *mathematically*, at a temperature of —273 deg. Cent. or —459.4 deg. Fahr. (the minus sign means negative, means below zero), the volume would disappear. Experiments show that this law, called the Law of Charles, holds true within the limits which we are able to measure. In making calculations in thermodynamics it is sometimes desired to use the absolute zero.

SENSIBLE AND LATENT HEAT.

It is important in boiler practice to know how water is affected by heat. At the temperature of 32 deg. Fahr. water changes from a solid to a liquid or from a liquid to a solid; ice forms or melts; it is a *critical* temperature. To melt one pound of ice at 32 degrees into water at 32 degrees, 144 heat units or B.t.u. must be applied to the ice; and, to freeze one pound at 32 degrees into ice at 32 degrees, 144 B.t.u. must be taken out of the water. To raise the temperature of one pound of water from 32 to 212 degrees, which is the boiling point at atmospheric pressure, 180 B.t.u. must be absorbed, and to cool it from 212 to 32 degrees, 180 B.t.u. must be

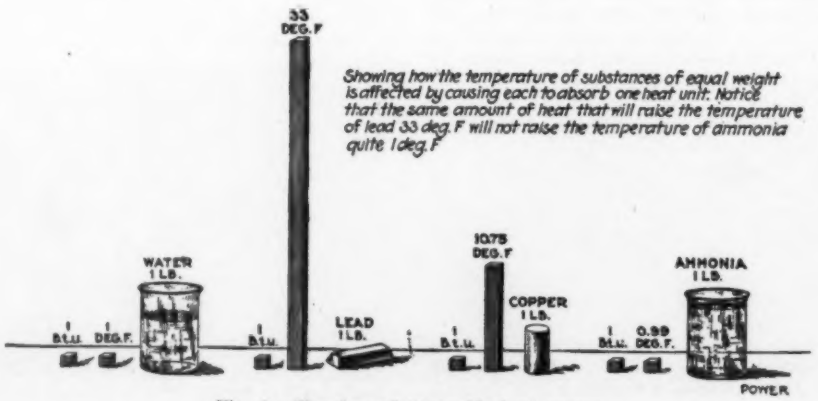

33 DEG. F
Showing how the temperature of substances of equal weight is affected by causing each to absorb one heat unit. Notice that the same amount of heat that will raise the temperature of lead 33 deg. F will not raise the temperature of ammonia quite 1 deg. F
WATER 1 LB.
1 B.t.u.
1 DEG. F.
LEAD 1 LB.
10.75 DEG. F
COPPER 1 LB.
AMMONIA 1 LB.
0.99 DEG. F.
POWER

Fig. 3.—Showing what specific heat means.

given up by the water. To cool one pound of water from 212 to 32 degrees, 180 B.t.u. must be taken from the water. But, to boil one pound at 32 degrees into steam at 212 degrees will require

180 B.t.u. + 970.4 B.t.u. = 1,150.4 B.t.u.

Remember that this is *above 32 deg. Fahr.* and not above the thermometer zero or the absolute zero.

Notice that the steam is no hotter than the water from which it was produced after the water reached 212 degrees, although it took over 5.3 times as much heat to turn it into steam as it did to raise its temperature from 32 degrees to 212 degrees.

The mercury in a thermometer placed in the water while it was being heated from 32 to 212 degrees, or the boiling point, would have risen from 32 to 212 degrees. You could *see* the water getting hotter; the thermometer would show that it was absorbing heat. But, after 212 degrees had been reached, and, although heat were still applied to the water, a thermometer would not show any increase in temperature even though all the water was boiled into steam, and we know that over five times as much heat was needed to make steam of the water as was necessary to get the water ready to make steam. Neither would a thermometer show that it required any additional heat to melt ice at 32 degrees into water at 32 degrees, or any removal of heat to cool water at 32 degrees into ice at the same temperature.

We have just considered the two kinds of heat known as sensible and latent heat. Sensible heat was that amount of heat applied to the water to raise its temperature from 32 to 212 degrees or the temperature at which steam began to form. It was sensible, i. e., it was apparent to the senses; in this case, the sense of sight when we saw the mercury rise in the thermometer. The relative amounts of these two kinds of heat are shown in Fig. 2.

The heat required to make steam of the water at 212 degrees was not apparent to the senses, except that we could see the steam escape as it was made, but we could not detect the added heat by the aid of a thermometer or by feeling the water. The heat was latent, and that is what is meant when *latent heat of vaporization* is mentioned. It is the heat required to turn a liquid into a gas without change of temperature. To boil into steam a pound of water at 32 degrees, then, requires 180 B.t.u. of sensible heat and 970.4 B.t.u. of latent heat, or a total of 1,150 B.t.u. And this latter amount is what is meant when *total heat* or *total heat of the steam* is spoken of, as in the steam tables. *Latent heat of fusion* is the heat that must be taken from a liquid to make it solidify without change of temperature, as when water at 32 deg. Fahr. freezes into ice.

THE MECHANICAL EQUIVALENT OF HEAT.

If a one-pound weight fell from a shelf 778 feet from the ground, it would strike the ground with 778 foot-pounds of energy. This number of foot-pounds is called the *mechanical equivalent of heat*, because with a perfect apparatus it would take the same amount of energy to raise the weight up to the shelf, as it would to raise the temperature of one pound of water 1 deg. Fahr.

So, when it is desired to express heat energy in terms of mechanical energy, we have

Mechanical energy = heat energy or B.t.u. × 778

and

$$\text{Heat energy or B. t. u.} = \frac{\text{mechanical energy}}{778}$$

If a steam plant could use all the heat in the coal it received, then all of this heat would be converted into work at the engine shaft. Thus, from a pound of coal containing 14,500 heat units per pound, we would get

14,500 × 778 = 11,281,000 foot-pounds

of mechanical energy.

The plant makes use of but very little of all the heat in the coal. The boiler, if handled well, will advantageously use, say, 80 per cent, or

14,500 × 0.80 = 11,600 B.t.u.

Now of this the engine, which we will assume is a good compound condensing one, will turn into work, say, 19 per cent of all the heat it receives, which in this case we assume to be 11,600 B.t.u. for each pound of coal burned in the boiler.

11,600 × 0.19 = 2,204 B.t.u.

For each pound of coal burned containing 14,500 B.t.u. there is available at the engine shaft only 2,204 B.t.u. The amount of heat turned into useful work multiplied by 100 and divided by the heat in the coal gives the percentage of the total available heat in the coal that was turned into work, or

$$\frac{2204 \times 100}{14{,}500} = 15.2 \text{ per cent.}$$

And this amount is called the *thermal efficiency* of the plant.

SPECIFIC HEAT.

You cannot soak up as much water with a wad of paper as with a sponge of equal volume. Neither will a granite block soak up as much as an ordinary red brick. And so on with various substances; their *capacities* for absorbing liquids are not the same.

The *capacities* of different substances for absorbing heat vary in the same way. If you put one heat unit into a pound of water, which is at, say, 62 deg. Fahr., you raise its temperature one degree, or to 63 deg. Fahr. If you put the same amount of heat into a pound of silver, its temperature will increase 18.1 deg. Fahr., and for lead it would increase the temperature 33 degrees; for copper, 10.75 degrees; for ammonia, 0.99 degree, and so on, each substance having its own peculiar capacity for absorbing heat to produce a given rise in temperature. This is shown in Fig. 3. This capacity is called the *specific heat* of a substance, because that amount will produce a temperature change in a given substance that it will not produce on any other; it is specific for that substance. *Specific heat*, then, is the *heat energy required to raise a unit weight of matter 1 degree as compared with the heat needed to raise a unit weight of water 1 degree.*

In order to compare the heat required to produce an increase of 1 degree in some substance, we use water as a standard, for water is in common use and requires one heat unit to produce an increase of one degree; its specific heat is 1, or unity. As used in engineering calculations, specific heat is a ratio; it expresses the relation that exists between two quantities, as

$$\text{specific heat} = \frac{\text{heat required to raise 1 lb. of matter 1 deg.}}{\text{heat required to raise 1 lb. of water 1 deg.}}$$

APPLICATION OF SPECIFIC HEAT.

In engineering it often is important to know how much heat is required to increase the temperature of a substance one degree, to know its specific heat.

For example, it is desired to know how much heat is carried away by the flue gases per pound of fuel burned. The specific heat of flue gas is generally taken as 0.24; i. e., it takes 0.24 B.t.u. to heat a pound of flue gas one degree. So to find the heat lost in the flue gases, we multiply the weight of gas made by a pound of fuel by the specific heat, or 0.24, and then multiply this product by the difference in temperature between the gases leaving the boiler and the air entering the furnace. The same general method applies for finding the amount of heat absorbed or given up by any substance.

The Calculation of the Condenser Dielectric Constant

By Kenneth Richardson

I WISH to make a condenser of a certain capacity for my wireless transmitter or receiver. Someone has kindly directed me to use the following formula:

$$C \text{ in micro-farads} = 0.0000002247 \times \frac{ka}{x}$$

In which a is the combined area in square inches of one side of all the sheets of dielectric between plates,

x is the average thickness in inches of the dielectrics between plates, and

k is the dielectric constant.

INDUCTIVE CAPACITY CONSTANTS OF CONDENSER DIELECTRICS.

Air	1.00
Beeswax	1.80 to 2.00
Glass	3.00 to 10.00
Gutta percha	3.80 to 3.90
Hard rubber	2.21 to 3.15
Mica	4.00 to 8.00
Paraffine wax	1.68 to 2.30
Paraffine oil	1.86 to 1.92
Petroleum	2.04 to 2.42
Pitch	1.75 to 1.90
Resin	2.50 to 2.60
Shellac	2.95 to 3.60
Turpentine	2.15 to 2.43
Vulcanite	2.45 to 2.50

In referring to a table of dielectric constants it is found that k is quite an indefinite quantity. For example, the constant of glass varies between 3 and 10, depending upon the quality. The dielectric constant cannot be known by the appearance of the substance. This is an electrical property of the substance and electrical means must be employed in order to arrive at its value.

For a certain capacity, then, say 0.005 M. F., how may I know the size and number of sheets or plates to use, since I do not know the exact dielectric constant of the material?

This is often the problem of those who design their own apparatus. Usually the dimensions are guessed at, resulting in an unbalanced outfit.

The method outlined will enable anyone with a wave meter to accurately calculate the dielectric constant of any insulator very easily.

Connect up the instruments comprising the closed circuit of the wireless transmitter in the usual manner. Adjust the helix for a certain wave, say 200 meters.

Our method of getting the dielectric constant is to make a small condenser of one or two plates of dielectric to be tested, this sample condenser to be substituted for the standard condenser in the closed circuit and the effect upon the wave-length noted on the meter. We can then know the exact capacity of the sample condenser, and from this know the dielectric constant by employing the simple formulas to follow.

It is necessary to get the exact inductance of the closed circuit part of helix which was adjusted for 200 meters wave. The helix inductance is found by the formula:

$$L \text{ in micro-henries} = \frac{101.5 \times N^2 r^2}{1 \times 1000}$$

In which N is the exact number of turns in circuit,

r is the radius of the helix in inches, and

l is the exact height in inches of the helix (effective turns in circuit only).

Let us assume a helix inductance of 10 M. H.

We now have both the wave-length and inductance of the circuit.

The sample condenser is now made and substituted, care being taken to have voltage of the spark coil on transformer reduced so as not to puncture the sample dielectric.

A very tiny spark is all that is necessary for the test.

Without disturbing adjustment of helix, operate coil and take a new reading on the wave meter. Let us assume the new reading to be 50 meters.

With the known inductance (10 M. H.) and the known wave-length (50 meters), the exact capacity of the sample condenser is found by the formula:

$$C \text{ in micro-farads} = \left\{\frac{W}{1885\sqrt{\times L}}\right\}^2$$

In which W is the wave-length in meters, and L is the inductance in micro-henries.

From this, our capacity is 0.000068 plus M. F.

When we know the exact capacity of the sample condenser, measurement is taken of the area of dielectric and the average thickness.

From these data, the exact dielectric constant is found by the formula:

$$K = \frac{Cx}{0.0000002247 \times a}$$

In which C is the capacity in micro-farads,

x is the average thickness in inches of the dielectric, and

a is the total area in square inches of one side of the dielectrics between plates.

In the formulas it must be kept in mind that:

(a) The capacity of a group of individual condensers in multiple is equal to the sum of the individual capacities.

(b) The capacity of a group of individual condensers in series is,

$$C = \frac{1}{\frac{1}{C_1} \text{ plus } \frac{1}{C_2} \text{ plus } \frac{1}{C_3} \text{ plus, etc.}}$$

In which C_1, C_2, C_3, etc., are the individual capacities and C is the joint capacity.

(c) Long connecting wires to condenser, spark gap, and helix will make the calculations inaccurate. It is advisable to employ all the helix or helices available for the tests.

(d) The open circuit should be entirely disconnected during the readings.

(e) Intense brush discharge from the edges of a condenser increase the capacity, throwing the calculations off. Avoid extreme high voltage.

The Cost of Building the Panama Canal

THE widely published official figures of the cost of the Panama Canal have possibly given the general public an exaggerated idea of the cost of the canal as a piece of engineering work. The statement has been made that the entire cost of the canal to the United States when completed will be in the neighborhood of $400,000,000, and it is a natural conclusion that the bulk of this expenditure has gone into the work of digging the canal and constructing the locks.

It will surprise many engineers even, we doubt not, to learn from figures published in the last number of the "Canal Record," that up to March 31st, 1914, the entire expenditure on the canal in the Department of Construction and Engineering had been only $204,087,000. The total expense up to the same date for all purposes connected with the canal was $322,659,000. The chief items in the account, apart from construction and engineering, were in round numbers, civil administration, $7,000,000; sanitation, $17,000,000; fortifications, $5,000,000, and general items, $90,000,000. Under this latter head are included the payment of $40,000,000 to the French Canal Company and $10,000,000 to the Republic of Panama. There is also included under this head very heavy expenditures for the reconstruction of the Panama Railroad, the construction and repair of buildings and the cleaning up of the cities of Colon and Panama.—*Engineering News.*

Electrical Driving for Rolling Mills—II*

Its Adaptation to Existing Steam-Driven Plants

By L. Rothera

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2022, Page 214, October 3, 1914

Before passing on to the method of applying the drive, it would perhaps be well to make a few remarks with regard to the advisability of using continuous current or 3-phase current as the source of power. This is a question which is fairly often settled by the conditions of supply prevailing in the district, but, if it is a question of generating power in the works themselves, very careful consideration must be given on account of a number of reasons. When looking into this question, the following factors must be considered:

(1) The most suitable type and cost of the central station plant.

(2) The cost of transmitting the power to the various points where it is required.

(3) The most suitable types of motors for the main drives; the most suitable types of motors for the auxiliary drives.

In the case of a works lying closely around the central station, the capital cost involved by installing a 3-phase plant or a continuous-current plant would be approximately the same, but should there be long distances to which considerable amounts of power have to be transmitted, then the extra cost of cable involved in the transmission of direct-current power will be very much in excess of that of a high-tension 3-phase scheme, since in the former case a voltage higher than 550 volts cannot be considered. The cost of the cables is thus very frequently the deciding factor as to whether 3-phase or continuous current shall be employed throughout the works. As against this cost must be set the, perhaps, more satisfactory working of continuous-current machines for driving auxiliaries, such as live rolls, saws or shears, but it must be pointed out that there are very many works equipped to-day with 3-phase motors for these purposes which are giving every satisfaction.

In the case of the main mill drives, the chief question in deciding the type of motor is, as to whether a variable speed is required or not. If a variable speed is required, as in the case of merchant mills, then a continuous-current motor, which can have its speed varied by means of shunt regulation of the field, is the simplest and best proposition for the purpose. If a constant speed only is required, as in the case of a sheet mill, the disadvantages of the 3-phase motor are not so great, although, even in such cases, it is very often a question as to whether the saving in efficiency by putting in the continuous-current motor does not outweigh the greater cheapness of the 3-phase motor. This saving in efficiency is due to a number of causes, which are perhaps of interest.

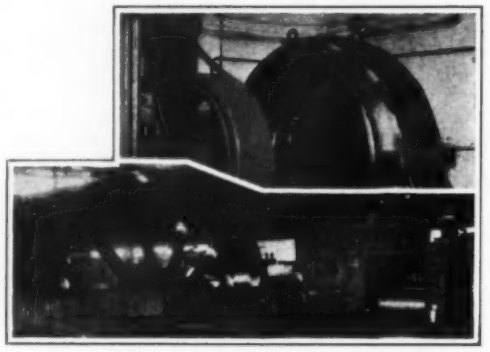
Take the case of a large sheet mill which requires a motor of, say, 1,000 or 1,500 horse-power, and a speed on the mill of 30 to 32 revolutions per minute. With a mill of this sort, a heavy flywheel of 100 to 150 tons would be necessary, running at the mill speed, in order to equalize the very heavy peak loads attendant on this class of work, and a fall in speed of at least 10 per cent from no-load to full-load would be necessary, so that proper use can be made of the stored energy.

Take now the case of a 3-phase motor. It is almost impossible to build such a machine running at a speed of 32 revolutions per minute, on account of the very large number of poles which would necessarily be entailed, and even if such a machine were built, the power factor would be so bad that very few power companies would permit it to be connected to their mains. It would thus be necessary to put in a higher speed motor with some form of reduction transmission between the motor and the mill.

In the case of a continuous-current motor, there is no difficulty attached to the building of a machine to run at this speed, so that in this case there is—first, a saving in the transmission losses, and secondly, a saving in slip resistance losses. These latter losses occur in the case of the 3-phase motor due to the fact that the only method of reducing the speed of a plain induction motor is by inserting resistances in the rotor circuit, and the loss in these resistances is proportional to the fall in speed. To reduce the speed 10 per cent on full-load, as is necessary to utilize beneficially the flywheel energy, a loss of 10 per cent would occur in the resistances. On some tests which were taken on a sheet mill it was found that the average loss due to the slip resistance losses represented between 13 and 15 per cent of the total energy consumed, and when to this loss is added the transmission loss, which may equal another 5 or 10 per cent, the advisability of installing a direct-coupled continuous-current motor to such a mill must be very carefully weighed.

This question of providing a varjable speed on the drive is one which has led to the evolution of a large number of alternative methods of enabling a 3-phase motor to work at a variable speed without the serious loss in efficiency which occurs in the case of an ordinary 3-phase induction motor, which, as mentioned above, can only have its speed varied by the insertion of resistances into the rotor circuit, which method involves a loss of power proportional to the fall in speed, that is, taking the case of a motor running with a normal speed of say 300 revolutions per minute, there will be a loss in power and efficiency of 50 per cent if the speed is reduced to 150 revolutions per minute. The method employed has usually been the addition of an auxiliary piece of apparatus which modifies the existing 3-phase motor and causes it to act more on the lines of a continuous-current shunt-wound motor.

Fig. 13.—Continuous current motor coupled to mill, shown in Fig. 12.



Figs. 14 and 15.—Typical rope drive on large sheet mill. Motive power, 1,060 horse-power. Heavy flywheel, weight of rim 100 tons, diameter 30 feet.

Fig. 16.—Direct current motor driving three mills, one mill being driven from each end of motor, the third by ropes.

The first method that may be mentioned is the addition of a frequency changer, as it is called, which consists of a small machine driven either mechanically from the main motor, or electrically through a separate small motor. This small machine is supplied with power from the slip-rings of the 3-phase motor and transforms this power into the correct pressure and frequency to enable it to be returned to the line. By this means, when the speed of the induction motor is reduced, the power which normally would be lost in slip resistances is returned to the line, thus making a great saving in efficiency.

A second method is to have a 3-phase motor and a small auxiliary continuous current motor coupled together, and an electrical connection between the rotor of the 3-phase motor and the commutator of the continuous current motor taking place by means of a separate small rotary converter. In this case the power which would normally be wasted in slip resistances is transmitted through the rotary converter to the auxiliary continuous current motor, which thus adds its power to the power of the main 3-phase motor.

A third method combines the rotary converter and the auxiliary continuous current motor, mentioned above, into 3-phase commutator motor, thus two machines only are employed instead of three.

Any one of the above methods enables a speed regulation to be obtained in practically as simple a manner as it is obtained in the case of an ordinary shunt wound continuous current machine, and the efficiency throughout the range of speed remains very high.

An alternative method of getting over the difficulty of the fixed speed attendant on the employment of 3-phase power is to provide step-pulleys on the motor, and to drive through ropes on to the mill. By this means a maximum of three or four speeds at most can be given efficiently, and any intermediate value has to be obtained by the insertion of rotor resistances, which, as explained above, is a wasteful method. The method of changing over from one speed to another is also cumbersome, due to the fact that the motor has to be capable of movement both axially and in a direction at right angles thereto in order to allow the same set of ropes to be used. In order to expedite this change-over, there have been cases where small motors have been put down for moving the beds. This type of drive, although somewhat cheaper than the systems mentioned above, has a further disadvantage in that it is not possible to obtain any desired speed between the upper and the lower limit, and experience has shown that in merchant mill work the difference of a few revolutions in the speed of the mill is of very great importance indeed for satisfactory working, and that it is worth while incurring a somewhat extra capital cost to enable this condition to be obtained.

With regard to the method of application of the drive, there are four alternatives which have to be considered:

(1) A direct coupled motor.
(2) A motor driving through gearing.
(3) A motor driving through a belt.
(4) A motor driving through ropes.

Modern practice to a great extent has gone in favor of the direct coupled drive, even for speeds as low as those required for a heavy sheet mill, namely 32 revolutions per minute. Of course, in the case of merchant mills where the speeds may vary from 100 revolutions per minute upward, the direct-coupled drive presents no difficulties, and the question of the difference in capital cost between a direct-coupled drive and a gear or rope drive has not to be so seriously considered as is the case in a very slow speed drive. In a great many cases, however, the extra additional cost of the slow speed drive is more than counterbalanced by the gain in efficiency due to the absence of any form of transmission losses between the motor and the mill. These losses are a heavy item in the yearly expenditure, as can be seen when the losses in the various forms of transmission are considered. Taking the case of gearing, it can be assumed with a fair degree of accuracy that the losses taking place in a single reduction represent about 5 per cent *of the power which is being transmitted*. This value is perhaps excessive when taken on a gearing which has just been newly put down, but for varied conditions of working, and when the gears have become somewhat worn, it is not safe to assume that any less loss than this takes place. In the case of a rope drive the percentage loss taking place in the drive alone is a somewhat moot point, some authorities giving the losses up to as much as 10 per cent, while others place the figure as low as 2 per cent. As, however, one of the first authorities on rope drives suggests that a figure of 5 per cent is a good working figure, it is probably quite safe to accept this figure as being the correct amount to take into account. Special emphasis in the case of a rope drive must be laid upon the fact that the loss occurring in the ropes remains practically constant whether the ropes are running light or transmitting power, and the loss can be taken *on the normal power which the ropes are designed to transmit*. In this respect, therefore, the rope drive is not as efficient as a gear drive, although it certainly provides a very nice flexible medium between the motor and the mill. Another drawback in the case of a rope drive is the amount of space taken up, and the cost of upkeep of the ropes, which is very considerable, the life of the ropes being a very variable figure, ranging from about two years to perhaps five or more.

With regard to a belt drive, this form of transmission has not been very extensively employed in this country for this class of work, but it has been used to a somewhat greater extent on the Continent, and has been employed for powers up to 1,800 horse-power normal and 3,600 horse-power maximum with, it is believed, very satisfactory results.

* Paper read before the Institution of Mechanical Engineers.

In order to show in a simple form the losses which may occur throughout the year due to transmission losses, a case is taken of a sheet mill with a normal power of 600 horse-power on the motor, and an average power taken by the mill of 200 horse-power. Assuming that the mill is working for 110 hours per week, and 50 weeks to the year, the losses in the case of a gear drive would be 5 per cent of 200 horse-power, namely 10 horse-power for 5,500 hours, while in the case of a rope drive the losses would be 5 per cent of 600 horse-power, namely 30 horse-power for the same number of hours. Taking the cost of power at 1 cent per unit, the loss in these two methods of drive as compared with the direct-coupled drive would be roughly $500 in the case of the gear drive, and $1,500 in the case of the rope drive, representing with a 10 per cent interest on the capital outlay $5,000 and $15,000 respectively of extra plant.

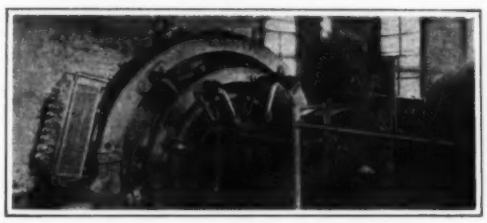
Where the question of converting an existing mill has to be considered, the method of drive adopted must be dependent, to a very large extent, on the lay-out of the works, as there may be other mills, roof columns, or other reasons, which may render any one of the drives mentioned above impracticable.

One of the first questions which arises when the conversion of an existing mill is contemplated is the length of time for which the mill will have to be shut down in order to make the change-over, and it is imperative, in most cases, that this time should be reduced to a minimum. This consideration is one which, in a number of cases, lends itself to the introduction of a rope drive, as the foundations of the motor and the motor itself can be put down without interfering with the working of the mill, and the mounting of the rope pulley for coupling to the mill is very often a matter of quite a short time, and sometimes not much more than a long week-end. In the case of a direct-coupled drive, a method of avoiding stoppage is shown by the photograph, Fig. 12, where a long intermediate spindle is introduced between the pinions and the motor, this spindle spanning the space taken up by the existing engine. The change-over in this case from the steam to the electric drive did not involve any stoppage of the mill. Fig. 13 shows the continuous-current motor coupled to this mill.

It is sometimes possible to put down the motor on the side remote from the steam-engine, and this was done on the second electrically-driven reversing mill which was installed. This plant has been working now for 5½ years, and no trouble whatever has been experienced through its having been found necessary to transmit the drive through the bottom spindle to the pinions—a view of the plant is shown in Fig. 3 (page 213). It may be said that when this plant was first put down the engine was retained in place so that it could be re-coupled to the mill in the event of anything going wrong with the electrical drive, but it has never been used since the electrical plant has been set to work. In some cases it is possible, by the introduction of another gear wheel, to put the motor in position without shutting down the plant, and in Fig. 7 is shown a 250 horse-power motor driving through gearing on to a sheet mill where this procedure was adopted.

When applying a motor drive to a mill, an important consideration is the weight of flywheel to be adopted, and this is a matter which can only be satisfactorily decided through experience. It is not a safe method to assume that the flywheel, as fitted to the existing engine, will be satisfactory in the case of a motor drive, since, when an engine is overloaded, it will slow down until finally it will stall. A motor, of course, does not act in the same way, but has a pre-determined drop in speed from no-load up to the maximum load which it can safely stand, and if this maximum load is exceeded, the circuit breaker or switch protecting the motor will operate, shutting down the plant. In the former case, that is, of the engine, the whole of the stored energy in the flywheel is available to pull the metal through the rolls in conjunction with the engine, while in the latter case, assuming a 20 per cent fall in speed between no-load and 100 per cent overload, only 36 per cent of the stored energy is available, after which the motor ceases to drive, leaving only the flywheel stored energy. This is, to some extent, counteracted by the fact that the permissible overload on the motor will be 100 per cent in excess of the normal power, while in the case of an engine the overload will not be much more than 25 per cent, but it can generally be stated that the flywheel will require to be heavier in the case of the motor drive than in the case of the engine. The heavier the wheel, of course, the steadier the power demanded from the motor, but here again the question of cost is the deciding factor, and a fluctuating load will not prove harmful to a motor provided that the maximum peaks are not excessive. This is clearly shown by the success of the motors employed for reversing mill work—where they are coupled direct to the pinions and take the full power demanded by the mill.

Fig. 17.—The rope-driven mill and one of the direct-coupled mills.



Figs. 18 and 19.—Variable speed motor, 600 brake horse-power. Speed, 300-450 revolutions per minute, driving rail mill.

Another question which arises if there is some form of transmission between the motor and the mill is, as to whether the flywheel be placed on the high-speed motor shaft, or be direct coupled to the slower speed mill. Modern practice in this respect has usually decided in favor of the flywheel connected to the mill, and this would appear to be the correct solution of the matter, as, in this position, the flywheel absorbs the peak loads of the mill before they come back on to the transmitting mechanism.

The cost of having a large slow speed flywheel is usually somewhat in excess of having a high speed smaller flywheel, but the difference is not, in many cases, very great on account of the fact that the full peak loads of the mill in the latter case have to be transmitted from the motor and flywheel through the gearing or ropes as the case may be. The size of the gearing, and the number of ropes, will have to be very materially increased to withstand this extra strain. As the ropes and gearing are usually admitted to be evils, the reduction of them to their smallest dimensions is advisable, and this can be done by designing them to transmit only the normal power of the motor and allowing excessive mill peaks to be taken up by the flywheel directly coupled to it.

A form of drive which has been suggested and employed in one or two cases is to mount the flywheel on the motor shaft, and to drive through a worm reduction gear on to the mill. This is a very interesting new departure, and time will show whether it possesses advantages over the better known drives. It would appear to be a very satisfactory method if a steady power is demanded, such as, for instance, a wire mill or cold roll drive in a tinplate mill where there are no heavy peak loads to be taken up by the flywheel, but where the full power of the motor and flywheel has to be transmitted through such a gear it is to be seen whether it can be made of sufficiently strong design to give an efficient working life commensurate to the initial cost of the plant.

The various types of drives mentioned above have been mostly shown by the preceding illustrations, and Figs. 14 and 15 show a typical rope drive on to a large sheet mill, the motor power being 1,060 horse-power with peak loads up to double this amount. The heavy flywheel necessary for this type of drive is shown very clearly in Fig. 15, the weight embodied in the rim being approximately 100 tons with a diameter of 30 feet.

Figs. 16 and 17 show a rather interesting drive which has been installed in an iron works where a motor has been put down for driving three mills, all of which require practically a 2 to 1 speed variation for dealing with the various classes of work. A direct-current motor is employed for the drive as shown in Fig. 16, one mill being driven from each end of the motor and the third by means of ropes. Fig. 17 shows the rope-driven mill and one of the direct-coupled mills.

Figs. 18 and 19 show a rail mill driven by means of ropes from a variable speed motor of 600 brake horse-power, the speed of the motor being variable between 300 and 450 revolutions per minute. In both the cases mentioned above, flywheels are fitted to the mills to equalize the loads which the motors have to take.

Utilization of the Waste Heat of Slag

Much has been done in the last few decades to utilize the heat in iron blast-furnace slags, the annual production of which amounts to close on 200,000,000 tons. If their temperature is taken at 1,500 deg. Cent., the quantity of heat they contain must be enormous, all of which is wasted.

Efforts were made some years ago by the late Sir Lowthian Bell to save this heat, but the state of engineering achievement in his time did not permit a satisfactory solution of the problem. Further experiments have been in progress at the Clarence works of Messrs. Bell Brothers, Middlesbrough, for some years, the patents being in the hands of the Slag Power Company. The first plan was to drop the molten slag as it comes from the blast furnaces into water, and use the steam thus produced in a low-pressure turbine. But the considerable quantities of hydrogen and sulphureted hydrogen produced along with the steam gave rise to difficulties in connection with obtaining the high vacuum necessary to the efficient working of the turbine. These difficulties were overcome, but a quantity of fine sulphur was also produced, and this it was found impossible to eliminate from the steam. Yet if it had not been removed it would have damaged the blades of the turbine with which it came into contact, and would also have blocked the steam passages. Another difficulty was caused by the fact that the hot blast-furnace slag when thrown into water froths up into a foam-like substance, which floats, and means had to be devised for submerging and removing it.

Instead of attempting to use directly in the turbine the dirty steam generated by the contact of the slag with the water, the plan finally adopted was to employ it indirectly for generating clean steam by means of a heat exchanger, the particular form adopted being a Kestner single-effect climbing film evaporator. The hot slag is run direct from the blast furnace into the primary generator, in which an upright shaft with four blades revolves, keeping the water in constant rotation. When the slag drops through the orifice the velocity of its fall carries it well below the lip, and before it rises to the surface it is swept by the moving water past the orifice and inside the seal. An elevator then lifts it from the generator and drops it through a second seal; by this time it is waterlogged and sinks, and it is then collected by a second elevator, which drops it into railway trucks for removal. The dirty steam passes from the generator to the evaporator, where it is used to produce clean steam, which is employed in the turbine. In the case of copper slag, the second elevator is not required, since the slag does not float in water, but immediately sinks.

Over 740 kilogrammes of water have been evaporated per 1,000 kilogrammes of blast-furnace slag containing 550,000 calories; deducting 18,000 calories removed with the slag at 100 deg. Cent. and 42,000 removed with the water taken up by the slag (on the assumption that it absorbs 50 per cent of water), the available heat is 490,000 calories, or, if an allowance of 25 per cent is made for loss, 367,500 calories, which divided by 622 give 590 kilogrammes of steam. As the result of many experiments, the average efficiency of the evaporator is found to be 91 per cent, but taking it at only 80 per cent the amount of clean steam available for the turbine is 472 kilogrammes, and this with a consumption of 13 kilogrammes of steam per horse-power, which is an excess of that guaranteed by the makers of the turbine with a vacuum of 28.5 inches and a vacuum of 7 inches over the water in the evaporator, means a yield of over 36 horse-power per 1,000 kilogrammes of slag.

Copper slag contains less heat than blast-furnace slag, the amount being found by experiment to be from 318 to 350 calories per kilogramme, and therefore by a similar calculation 1,000 kilogrammes will produce 281 kilogrammes of clean steam, equivalent to a yield of, say 21 horse-power in the turbine.

It is estimated that with a 1,000-kilowatt plant with 75 per cent load, the cost of generating 1 kilowatt would be 0.32d., whereas with a high-pressure steam plant using coal at 14s. 6d. a ton it would be 0.48d., the economy realized by the aid of the heat from the slag being thus 0.16d. per kilowatt, which under the conditions stated would amount to £4,300 a year. It is stated that the upkeep of the generator and evaporator is small. As the slag goes directly into the water, only steam at 100 deg. Cent. comes in contact with the plant, which is thus not subjected to any great differences of temperature, while experience indicates that there is no action from the gases on the plates or tubes of the evaporator, provided they are kept clean.—*Engineering and Mining Journal.*

Stress Distribution in Materials*

A Review of Various Methods Suggested for the Solution of Important Engineering Problems

By Prof. E. G. Coker, M.A., D.Sc., M.Inst.C.E.

THE subject of stress distribution in materials, which I have chosen for this address, is not one which an engineer can claim as his peculiar province, for it has been and still is a fruitful field of investigation for the mathematician, the physicist and the geologist, and has always been so since the commencement of scientific inquiry.

The development of architecture from the earliest dwellings of savage races to the great temples of Egypt and Greece, the bridges and aqueducts of the Romans, and the mediæval buildings of Europe, all bear witness to the accumulation of practical knowledge of the properties of materials and of the stress distribution in structures, which we cannot fail to admire, although we know far too little of the way in which these ancient structures were planned and constructed. The magnificent arched and domed buildings of the Roman period, and the stately cathedrals of later times with their wealth of architectural form—tower and spire, flying buttress and vaulting—all show how considerable was the practical knowledge of stress distribution possessed by the master builders who planned and carried out these great structures. We, who inherit these buildings as a precious legacy of bygone ages, have at our command far greater resources in the accumulated knowledge of centuries of scientific discovery and invention, and can build more complex structures—great bridges of steel, towering frameworks covered by a thin veneer of masonry, and floating arsenals of the most bewildering intricacy. All these we can show to our credit as the result of the steady increase of scientific knowledge applied to practical ends, but, even now, knowledge of the stresses which come upon these complex structures and machines is relatively small. Scientific investigations of engineering problems of stress still lag behind constructive ability, and defective knowledge is obscured more or less by approximate theories and buttressed by factors of safety, which serve in one instance perhaps, but show in others that they have merely given a sense of fancied security with no real basis, and are more properly factors of ignorance, to be discarded at the earliest moment. Who, for example, can say with certainty what is the stress distribution throughout the compression members of a great bridge, built up of complicated steel shapes and plates, united by stiffening angles, gusset plates, and innumerable rivets? There is probably good reason for the belief that a great strut is relatively weaker than a small one, when both are designed according to the same approximate formulæ now used in current practice, and engineers are unwilling to take the responsibility for such members in a great structure, without providing a very ample margin of safety to cover the contingencies arising from lack of precise knowledge of the strength of these members. So numerous are the problems which arise in the design and construction of machines and structures, that it is perhaps not unprofitable to devote a short hour to the consideration of some of the available means which an engineer can use as a guide for his applications of science to construction, since of whatever kind are the professional activities he pursues, his place in the scheme of affairs mainly depends on his ability to make machines and structures for directing and modifying natural sources of power in known ways, or applying them to new purposes as scientific discoveries advance the boundaries of knowledge.

It is of some help to our appreciation of the achievements of the great constructors of past ages, if we remember that they probably all held the erroneous view that materials of construction are perfectly rigid bodies, and, indeed, we know that as late as 1638 Galileo Galilei was of that opinion, and that he came to an entirely wrong conclusion as regards the stress distribution in a loaded cantilever.

From the standpoint of the engineer, nothing is of more practical importance than the great discoveries of Hooke and Young, that bodies like metal, wood, and stone are "springy" and have a simple linear relation between stress and strain. It is probably within the mark to say that nine tenths of all the experimental investigations on stress distributions in structures have been entirely based on the fundamental principles which they enunciated, and new uses are continually arising. The recent application of the steam turbine to the propulsion of ships produced a profound change in marine-engine practice, and incidentally involved an entire reconstruction of methods for obtaining the horse-power developed, which had been gradually perfected from the time of Watt, but were absolutely useless for the new system of propulsion. Hooke's discovery of the essential springiness of metals enabled engineers quickly to devise new instruments capable of accurately measuring the infinitesimal angular distortions of propeller shafts, and from these to determine the horse-power transmitted by the aid of an appropriate modulus.

The construction of tall buildings affords another example where advantage has been taken to determine the loads upon columns by measuring the minute diminutions of length as the structure proceeds, thereby affording a valuable check upon the calculations for these members, and a reliable indication of the pressures supported by the foundations.

The distribution of stress in buildings constructed of composite materials like concrete reinforced with steel has also been examined by similar methods, and much data for guidance in future constructional work has been obtained, especially in the United States of America.

The still more difficult problems involved in the determination of the stresses in joints and fastenings of complicated structures have often been investigated by purely mechanical measurements of strain, and the experimental investigations of Professors Barraclough and Gibson and their pupils upon the distribution of stress due to riveted joints and curved plates of boiler shells afford a notable example of the successful application of the measurement of small strains to a stress problem of great complexity.

That "science is measurement" is here sufficiently obvious, and it seems only due to the memory of that great engineer, Sir. Joseph Whitworth, to refer to his great mechanical achievements of a true plane and well-nigh perfect screw, which enabled him to measure changes of one millionth of an inch, and thereby gave experimental investigations of strains a new impetus, which is reflected in subsequent work on the subject. Nor must we forget the no less important exposition, by Kelvin and Tait, of the scientific principles of instrument construction which have done so much for the design of instruments for the precise measurement of strains.

Mechanical measurements cannot, however, completely satisfy all our modern requirements, since they are essentially average values, and fail to accommodate themselves to many of the problems which press for solution.

In the quest for exact experimental knowledge, the measurement of stress at a point becomes of paramount importance, and we may, therefore, inquire what further means the researches of pure science have placed at our disposal for the determination of stress distribution in materials.

It is well known that many materials when tested to destruction show a considerable rise of temperature at the place of fracture, especially in very ductile materials; but Weber was the first to discover that a metal wire when stretched within the elastic limit is cooled by the action of the load, and this result was deducted later from the laws of thermo-elastic behavior of materials by Lord Kelvin, who showed that tension and compression loads produce opposite effects, and that materials which have the property of contracting with rise of temperature show thermal effects of the reverse kind. Although the changes of temperature produced by stress are small within the elastic range—less than 1 deg. Cent. for most materials—yet their effect upon a thermo-couple is readily measurable if the equilibrating effects of surrounding bodies are neutralized or allowed for, so that stress distribution can be determined by thermal measurements at a point. The correction for such disturbing causes is usually an important factor, and is generally so large that experimental work is more suitable for the laboratory than the workshop; but if all necessary precautions are taken a linear relation of stress to strain can be shown to hold up to the elastic limit of the material, while above this point the break-down of the structure causes a rise of temperature of so marked a character that it has been utilized by several investigators as an indication of the yield point.

Experiments, upon members subjected to tension, compression, and bending, show that thermal phenomena afford trustworthy indications of the stress in materials so diverse as a rolled-steel section, a block of cement, and beams of stone and slate. Although no attempt appears to have been made to investigate stress distributions of any great complexity, it seems not unlikely that thermal methods of investigation will ultimately prove of considerable value.

The transparency of metals to Röntgen rays is another phenomenon which has often been suggested as likely to be of service for work on stress distribution in materials, and Mr. Howgrave Graham and I have examined a number of rolled metals under stress up to the breaking point, without, however, discovering any change in the appearance of the material as seen on a fluorescent screen. Although our experiments showed no preceptible change, it is, of course, not impossible that an effect may have escaped our notice.

Another and still more fascinating field of research on stress distribution is afforded by the doubly retractive properties of transparent bodies under stress, a discovery made by Sir David Brewster almost exactly one hundred years ago, and but rarely made use of since by engineers, although Brewster himself immediately saw its value for experimental purposes, and suggested that models of arches might be made of glass, and the effects of stress due to loading rendered visible in polarized light.

Brewster carried his investigations further, by the invention of a "chromatic teinometer" for investigating the nature of strains, and consisting of plates or bars of glass subjected to flexure in definite ways for comparison with the body under stress.

At a much later date (1841), Neumann developed an elaborate theory for the analysis of strain in transparent bodies due to load, unequal temperature, and set, while still later the youthful genius of Clerk-Maxwell supplied an algebraic solution for the stress distribution in any plate subjected to stresses in its own plane.

The application of optical investigation to the determination of stress distribution in engineering structures and machines has, however, been hindered by causes which, although apparently insignificant, have been very real obstacles, and among these was the absence of a transparent material which could be fashioned into shapes suitable for investigating technical problems. It is not an easy matter, for example, to construct a glass model of a bridge free from internal stress, in the manner suggested by Brewster; and, moreover, glass is extremely fragile under load, especially in cases where the stress distribution in it varies very much, while the cost of construction is very great. Happily there is now no necessity to employ glass for experimental investigation on engineering problems, since modern chemistry has supplied artificial bodies, such as the nitro-cellulose compounds which have optical properties very little inferior to glass, are able to bear great stresses without injury, and also are capable of being fashioned with the ease and certainty of a wooden model. Photographic processes are also able to reproduce the brilliant color effects caused by stress in transparent materials, so that permanent records can now be made for future reference.

The construction of polariscopes for examining models on a large scale is very essential for technical research, and the great scarcity of Iceland spar of sufficient purity and size for use as Nicol's prisms has caused much attention to be paid to the construction of apparatus for producing plane polarized light by the aid of sheets of glass. Fortunately this presents little difficulty, and although the light is not nearly so well polarized as that obtained from a Nicol's prism it is sufficiently so for the purpose. Large quarter-wave plates of mica have also been constructed by my colleague, Prof. Silvanus Thompson, F.R.S., for obtaining circularly polarized light, and these have proved sufficiently exact and exceedingly useful for large models.

It is of importance to show that the stress distribution revealed by a polarized beam of light passing through an elastic transparent material in no ways differs from that obtained by other means, and evidence is available in modern researches, especially by Filon, that the experimental results obtained with glass agree with those of the theory of elasticity, while a satisfactory agreement of a similar kind has also been obtained with nitro-cellulose compounds, although not in so complete and direct a manner. Such an agreement may be expected on theoretical grounds, since the values of the elastic constants do not affect the fundamental equations for stresses in a plane, and although for three-dimensional stress the effect of the stretch-squeeze ratio causes some difference, yet this is usually negligible.

Most of the physical constants of glass have been determined with very considerable accuracy, but other transparent substances have so far received little attention, and their optical constants are not well known. The stress-strain relations of glass and nitro-cellulose have been determined with considerable accuracy, and a useful idea of their relation to metals may be gained from the values of the stretch-modulus, E, and the stretch-squeeze ratio, σ.

The accompanying table shows some average values for a few important materials, and it is of interest to note

* An address to the Engineering Section of the British Association for the Advancement of Science by Prof. E. G. Coker, M.A., D.Sc., M.Inst.C.E., President of the Section.

that the stretch-squeeze ratios of cast iron and plate-glass are very similar, while the values of the stretch modulus are nearly as three to two. These two materials also possess other like characteristics: they are both very brittle, and possess well-developed crystalline structure, so that we may expect the properties of cast iron under stress to be very faithfully followed by plate-glass.

Material.	E	σ
Steel	30,000,000	0.25
Wrought iron	28,000,000	0.28
Cast iron	15,000,000	0.25
Plate-glass	10,500,000	0.23
Nitro-cellulose	260,000 to 300,000	0.40

The high values of the stretch modulus for steel and wrought iron are not, apparently, approached by any transparent material having similar ductile properties, but although nitro-cellulose has a stretch modulus of rather less than one hundredth that of steel, its stress-strain properties are not unlike. In some recent experiments with a mininture testing machine fitted with an arrangement for recording the stress-strain relations of xylonite throughout the whole range of stress up to fracture, the main characteristics of steel appear on a very much reduced scale, and give additional confidence that the results of optical experiments on this material are applicable to metal structures.

The complete analysis of stress distribution in a plate is not, however, a simple matter, and the analysis of Clerk-Maxwell was intended to provide a solution based on the properties of the isochromatic and isoclinic lines, coupled with the law that the optical effect is proportional to the difference of the principal stresses at a point, and to the thickness of the plate.

A principal stress perpendicular to the bounding planes is assumed to have no optical effect; but since many cases have arisen where there are three principal stress components, it seemed desirable to examine such a case experimentally.

Some observations on circular plates clamped at the edges and uniformly loaded over one face, showed that the bending stresses produced in the plate caused very little optical effect, since the tension and compression stresses neutralized one another, while the shear effects also appeared to be practically negligible. The only remaining stresses of importance were those caused by the clamping plates at the boundary, which produced radial and circumferential stresses having circular symmetry, and as the optical effects of these latter disappeared at a small distance from the edge, a field of view was obtained in which the optical effects of load applied perpendicularly to the plate were quite small, even when the internal stresses were very great.

Two circular plates clamped together to enclose a space between them may therefore be used as windows for observing the effect of a uniform pressure upon a transparent specimen, which latter may be a plate with its faces parallel to the end plates closing the chamber. If cubical compression is applied by a fluid, the principal stresses in the plane of the plate produce opposing optical effects, and any remaining effect is due to perpendicular pressures on the faces. The arrangement of experimental apparatus, therefore, took the form of a pair of transparent windows separated by an annular disk, and firmly clamped together by collars The central chamber so formed was subjected to pressure of air, or other fluid, up to about one thousand pounds per square inch, and afterward the specimen was introduced and the same pressure applied; but no visible change of effect could be observed. Finally, the specimen was set in the field of view outside the chamber, and pressure again applied by the fluid, but still no change was apparent. In all three cases the optical effects produced were small, and practically alike, so that the experimental evidence appears to warrant the conclusion that a principal stress in the direction of an incident beam of polarized light has no optical effect in a thin plate, or at any rate is so small that it may be neglected.

That the retardation between the ordinary and extraordinary rays is proportional to the stress difference perpendicular to the incident beam within the elastic limit of the material may, therefore, be taken as reasonably accurate, although future research may show that it is only an approximation, or even that it is more accurate to commence from a fundamental strain equation; but according to present knowledge there appears to be no warrant for such a procedure.

A more pressing difficulty arises with regard to the optical constant connecting the wave-length retardation with the stress difference. The recent researches of Filon on glass show that the value of this constant is curiously dependent on the previous history of the material, especially as regards its heat treatment. Until further knowledge is gained on this matter it appears to be necessary to guard against errors in stress measurement from this cause by a careful selection and treatment of the material used, since for other artificial bodies we may find that the variation in the constant is not less in magnitude, and is at least as complex as in glass. In some instances the stress optical coefficient may be dispensed with, and Filon has shown, in cases where a theory of stress distribution has been worked out and it is desired to compare it with the results of optical measurements, that the isoclinic lines offer many advantages, since they are independent of photo-elastic constants, and the material need only be subjected to small stresses.

The experimental analysis of stress distribution in a body depends on the possibility of finding the magnitudes and directions of the principal stresses at every point, and in practice it is found the simplest plan to determine the directions of stress from the lines of equal inclination obtained in plane polarized light, and to measure the stress difference by comparison with a wave-length standard, such as a Babinet compensator, or by comparison with a simple tension member set along one of the lines of principal stress, and loaded until the total effect produced is a dark field denoting a zero value. The difference of the principal stresses is then measured in terms of a simple tension. This alone is insufficient to determine the distribution, unless one of the principal stresses is zero, and, in general another independent measure must be obtained. This is very conveniently supplied by the change in the lateral dimensions of the plate under stress, since this change may be taken, in the absence of a third principal stress, as proportional to the generalized sum of the principal stresses throughout the thickness.

The determination of the lateral strains in a comparatively thin plate, forming part of a model of a machine or structure, necessitates measurements of extremely minute linear quantities. If, for example, a plate of xylonite is taken, of the maximum thickness obtainable for optical work, a simple calculation shows that these strains must be measured to an accuracy of one or two millionths of an inch. Several instruments have been designed and constructed for this purpose, to fulfil conditions which appear to be essential for successful use. It is necessary to avoid all chance of injury to the surface of a transparent material, so that the measuring points of an instrument can only be pressed lightly against the surface, and the weight must, therefore, be supported independently of the model. In instruments so far constructed, the measuring mechanism is carried on a U-shaped frame, for convenience of movement from point to point of the specimen. One measuring needle is secured and operated by a calibrating screw, and the other is free to move a multiplying lever system, and thereby tilt a mirror to give an angular deflection, which latter is calibrated by reference to the standard screw when the instrument has been finally secured in place. In recent work the labor of accurately setting the instrument in a number of different positions has proved so great, that my assistant, Mr. F. H. Withycombe, has designed a useful adjunct in the form of a mechanical slide-rest, to effect the required changes easily and expeditiously. In one arrangement, a bracket carries the measuring instrument on a three-point support, and movement is effected by slides arranged to give displacements along three axes at right angles, and their amounts are measured by micrometer screws to an accuracy of rather less than one thousandth of an inch.

These methods of stress determination avoid the difficulties of the Clerk-Maxwell analysis, which necessitates the determination of the equations to both families of isochromatic and isoclinic bands, usually a mathematical problem of considerable complexity. In some simple cases, Mr. Scoble and I have verified the accuracy of the method of lateral measurements for determining the sum of the principal stresses, by comparing the calculated stresses with the experimental values obtained in a plate of transparent material. We have lately carried these experiments a stage further, and have shown that the measured sums of the principal stresses in steel agree with the calculated values. This experimental solution, in fact, gives the stress at a point in a plate, if the conditions are those assumed by the mathematical case of a plate where generalized equations of stress apply.

It is at once obvious, if the utility of experiments on models of this kind is admitted, that experimental evidence is available on a variety of practical engineering problems covering a very wide field of practice, not merely qualitative, but quantitative, and approximating to the needs of the physicist and mathematician, and well within the known variations of the materials with which the engineer has to deal in his daily practice.

During the last few years much attention has been paid to the determination of the stresses in structural elements of primary importance, but only a small number of cases have been examined, since even the simplest problems have proved somewhat difficult, and much time and labor have been spent in perfecting optical and mechanical appliances to suit the special conditions required for investigations on transparent models. A simple example of a case easily examined and of practical importance is that of a tension member subjected to an eccentric load. The optical effects here show a linear distribution of stress due to the combination of direct pull and bending, while the neutral axis moves toward the tension side as the stress increases. Not only can these effects be measured, but if the specimen begins to fail some indication is obtained of the way in which the stress distribution is changed to meet the new conditions, and there is found a tendency to an equalization of the maximum stress at the boundary, although at present the form of the curve of distribution beyond the elastic limit is largely conjectural.

A case like that of a very short member subjected to direct compression is also not without interest, partly because it reveals unexpected difficulties. In the first place it is not easy to apply a pure compression stress, and if the surfaces in contact are not of the same materials it appears to be practically impossible, since the lateral changes are unlike, and shear stress is therefore produced at the plane of the surfaces in contact. In a short member this shear has a very important influence, and by interposing a thin layer of a material, such as india-rubber, between the pressure plates and the short transparent-block, the artificial shear effect produced by the india-rubber is easily shown to influence the distribution throughout, and to increase the stress in a very marked way. Experiments on transparent materials show that the increase of stress may be twenty per cent or even more. Such an effect is known to take place when cubes of stone are crushed between lead plates, and optical investigations on models have enabled a quantitative measure of the effect to be ascertained in this and other cases, thereby confirming the theoretical investigations of Filon on the distribution of stress in such members under various practical systems of loading.

The local effects produced near the points of application of a load are usually of considerable importance, and their influence on the stress distribution in beams has been examined by Carus-Wilson.

The stress effects produced by discontinuities in materials are also of considerable interest, and the cases arising from the necessities of construction are infinite in their variety.

The practical importance of an accurate knowledge of the change in stress distribution produced by changes of section in a member is so thoroughly appreciated that it needs no insistence, and it has received much attention from a mathematical point of view. Thus the local effect of a spherical cavity in a member subjected to uniform tension or compression load has been shown by Love to double the intensity very nearly, while Kirsch has shown that a small cylindrical hole in a tension member trebles the stress intensity. If the hole is elliptical the increase of stress may be still greater, and Inglis has shown, among other interesting cases, that if the minor axis of the ellipse is parallel to the direction of the applied load in a tension member, the stress intensity is increased by an amount measured by twice the ratio of the axis of the ellipse.

A crack, considered as the limiting case of an elliptical hole, is thus seen to give extremely great stresses at the ends, tending toward infinite values for an extremely fine crack.

Optical experiments afford an independent means of examining the alterations of stress intensity produced by discontinuities, and the results are found to agree remarkably well with those obtained from the theory of elasticity. The stress at the boundary of a small cylindrical hole in a plate has been found to be almost exactly three times the stress in the full plate, and the effects of holes comparable with the width of the tension member have also been examined in some detail.

In the case of a rivet just filling the hole and exerting no tangential effect at the boundary, there is a lessened tension stress across the minimum section at the boundary hole, accompanied by a marked radial tension. These effects have been recently confirmed in a mathematical discussion by Suyehiro. Other cases give satisfactory agreement with calculation, and we may therefore feel some confidence that experimental investigation will prove useful in some of the very complicated cases arising out of engineering practice where analysis is difficult, if not impossible.

The effects of overstress in materials may also be examined by optical means, and although the laws relating to stress distribution in overstressed transparent material are not known, the general effects observed in simple cases are fairly evident. If, for example, a tension member of glass is stressed, there is no ductile yielding of the material, and the stress will therefore rise very rapidly at the boundary of a small hole, and fracture will therefore occur with a moderate load. If, however, a ductile transparent material is employed, and the material shows signs of failure at the hole, the breakdown of the structure spreads outward as the load is increased, until we may have a condition in which, within the elastic limit, the curve of stress intensity at the minimum section accords with calculation, but at the overstressed part the stress tends to equalize, and the curve of intensity tends to become horizontal near the hole. The mean value of this part of the stress distribution may be inferred from the difference between the total load and the measured values below the region of failure; but the true

distribution of the overstress has not been accurately determined, so that the shape of this peak is largely conjectural.

The effects of groups of rivets such as occur in bridges, boilers, and structural members of all kinds, afford ample scope for further inquiry; but before more exact knowledge can be gained of the condition of stress in a complicated riveted joint it appears necessary to examine thoroughly the very simple cases.

Other interesting cases of discontinuity in structure are afforded by the engine hatchways, gun-turrets, funnel openings, and the like, in ships' decks, and some progress in this direction has been made by experiments on model decks, subjected to loads like those produced when a vessel meets the waves due to a head sea.

Even if the utility of transparent models is left out of account, it is generally acknowledged that many engineering problems are often simplified by the use of models of machines and structures on a small scale, where circumstances forbid experimental examination of the actual work. No defense of their use is, I think, necessary, since the employment of models is a characteristic feature of British methods, not limited to engineers. Kelvin did not disdain their use, and his successors, who have done so much to advance knowledge of the ether and the atomic dust, have freely employed their great ingenuity in the construction of mechanical models and diagrams to explain their views, as in the Lodge cog-wheel diagrams of the ether, the planetary systems of atoms of J. J. Thomson and Rutherford, and the grouping of elements by Soddy.

Engineers have not the same great difficulties which confront those who are advancing the boundaries of pure science; their models are very much what they please to make them; but, even then, problems arise which are sufficiently difficult to tax all the resources of applied science. The behavior of models considered as similar structures is, therefore, a subject which engineers are bound to investigate in order to determine the effects of fixed and moving loads, the action of wind, the pressure and frictional effects of steam and other fluids, and many other problems.

In the majority of cases the simplest and the most direct method is the experimental study of a model, from which to obtain the data required for calculating effects on a full-sized structure, and hence the laws of similarity have received a very close scrutiny.

Although most valuable information can be obtained from models, their usefulness is clearly limited. The effects of the dead weight of a structure are proportional to the cube of the linear dimensions, and are, therefore, not usually measurable on a model except in exceptional circumstances, as, for instance, where elastic jellies are employed, as in the well-known investigations of Pearson on the stress distribution in reservoir dams. Nor are questions of stability easy to solve, since the forces producing instability are proportional to the size of the model. On the other hand, stress effects due to applications of load may be measured by the strains produced in a model of the same material, if the loads are proportional to the squares of the linear dimensions. The effects of applied load are studied even better in a model constructed of transparent material, since the variation of stress from point to point can be studied with much greater ease and certainty.

As detailed models of this latter kind present some variations from the usual laws of similarity, it may be of interest to indicate their nature. Questions of deformation clearly involve the elastic constants of the transparent material and their relation to those of the proposed structure, while stress distribution in the solid is influenced by the value of Poisson's ratio. This latter effect is quite small for glass, but may become appreciable with other substance. It is negligible in a model of any material which approximates to a thin plate stressed by forces in its own plane.

The optical effects for any given load are, moreover, independent of the thickness of the material, and depend upon the stress difference, so that color effects are obtained which may be regarded as pictures of shear stress throughout the model. Modern researches on ductile materials like structural steel indicate that such materials fail at some limiting value of shearing stress, and since the places where these limiting values are reached in the model are visible to the eye, the weak places in the design of a structure can be ascertained and a faulty design corrected by purely experimental means.

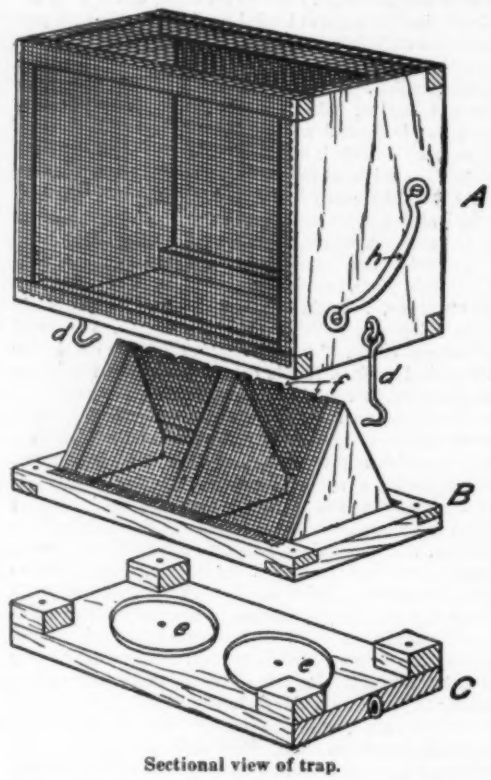
In this connection it is of interest to mention that M. Mesnager, the chief engineer of bridges and roads to the French Government, has recently constructed an elaborate model in glass of a design for an arched bridge of about 310 feet span. This investigation was considered advisable for a work of this magnitude constructed of reinforced concrete, in order to check the calculations, especially of maximum stresses in the arched ribs, which latter were assumed to be fixed at the ends.

The effects of reinforcements were allowed for by determining equivalent sections of glass for the members of the model. Many difficulties had to be overcome in the production of a model free from optical defects, but these were all successfully surmounted. The stresses in the model were determined by aid of a Babinet compensator, and formed a valuable check upon the calculations for a structure of this great magnitude and somewhat unusual design.

In this brief and incomplete account of a small branch of applied science relating to engineering the fundamental importance of discoveries in pure science is manifest.

A Homemade Fly Trap

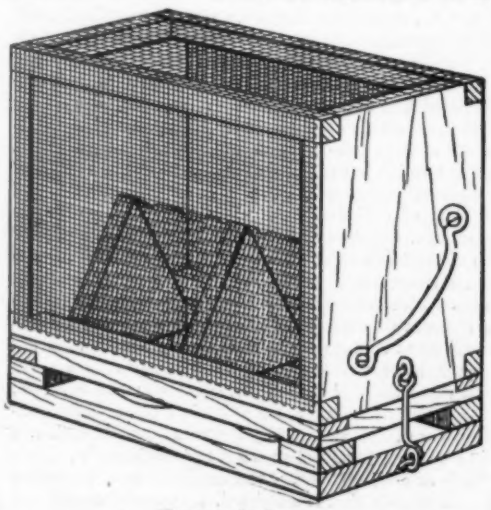
A RECENT issue of the *Weekly News Letter to Crop Correspondents*, issued by the Department of Agriculture, gives a description of a cheap and easily constructed fly trap that was sent to the Department by a farm demonstration agent in South Carolina, where



Sectional view of trap.

it is being used most successfully in the work of home sanitation.

"These traps can be made any size to suit," says the department's agent, "but the most popular size in my



Trap ready for use.

work is 16 inches long, 12 inches high, and 8 inches wide. I also make some as large as 24 inches long, 18 inches high, and 12 inches wide. The material for these traps costs from 10 to 20 cents, and can be put together by anyone handy with tools in a short while." The trap may be baited with sour milk, a piece of banana, a fruit skin, or similar substance. This should be removed at night or it will attract ants. At the same time, the flies which have been caught should be killed by pouring hot water over the trap or leaving it immersed in water until the flies are died.

The fly trap is made in three distinct parts *A*, *B*, and *C*, that may be detached from one another by unfastening the hooks *d* that hold them together at either end. The trap is unhooked in order to place the bait on the bottom section *c*. The bait is placed on two pieces of tin *e* tacked to this bottom section. In the sample trap that was forwarded to the department these pieces of tin were circular tops of paint or milk cans, which can be removed by prying up with a knife.

The middle section *B* of the trap consists of a screen-covered frame that resembles a small gable roof through which there are six holes *f* to let the flies into the uppermost section *A*, which is merely the screened-in cage that is set down over the other two parts *B* and *C*.

The handle *h*, of course, is unnecessary, but will be found convenient when the trap is immersed in water to kill the flies.

The department's agents, in their demonstration visits to the different farms, take the fly traps with them. They interest the housewife in them, and set one up in her home to show what it can accomplish. The results of the demonstrations have been so successful that almost every farmer who sees the trap wants one, and many of them have been putting traps together in accordance with the instructions of the agent.

The traps have done much to arouse the interest of the rural population of South Carolina in fly extermination, the necessity for which is not always felt as strongly on the farm as it is in the crowded city, where these vermin make themselves more obnoxious.

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